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FOOD ADULTERATION AND THE PURE FOOD LAW.*

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On the 26th day of June, 1895, a little over nineteen months ago, the Legislature of Pennsylvania passed the first general act regulating the sale of food within this Commonwealth, and providing against the adulteration of all articles of food and drink.

Judging from the comparatively short time that has elapsed since the question of food adulteration has received such general attention at the hands of our legislators, it might be supposed that the sophistication of food-stuffs is itself of very recent origin. Not only is this not the case, but the history of the subject indicates very clearly that ever since the day when barter and trade arose, ever since the time when commerce began to flourish, the instincts of

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gain and profit in the human breast have led men to impose upon their fellow-beings, and to offer for sale food and drink in a fraudulent and adulterated form.

It is naturally a difficult matter to state how early in the history of the world's civilization the practice of food adulteration began. Not only are the records of those early centuries incomplete and uncertain, but the intellectual and commercial development was so meager as to preclude the possibility of falsification, except within the very narrowest limits.

I believe, however, that we are safe in assuming that in ancient Egypt, even if deliberate adulteration was unknown, the distinction between pure and impure substances already existed. For example, in the Book of Exodus, under the laws which govern the construction of the tabernacle and its appurtenances, the children of Israel are explicitly commanded to bring *pure* olive oil for the lighting of the ark. If we remember Henry George's statement that the ancient Hebrew institutions show in so many points the influence of Egyptian ideas and customs, and that what is remarkable is the dissimilarity, we will not be stretching the imagination too far in assuming that olive oil in an impure and adulterated form was in use among the Egyptians.

The Bible itself contains no direct reference to food adulteration, nor are there any laws mentioned that control it. In the later rabbinical literature, however, and particularly in the Talmud, are given numbers of opinions of the rabbis as to what shall constitute a pure or an impure food. In the addidamenta to the Talmud, known as the "Tosefta," which are supposed to have been written in the first or second century before Christ, the following adulterations are mentioned: The addition of water to wine; the use of the juice of the glaucion in oil, to pass for poppy oil. The glaucion was a plant like the horned poppy, which was, in ancient times, often fraudulently substituted for poppy. There is likewise mentioned the use of the juice of the fruit of the arbutus, or wild strawberry tree, in honey; the use of flour in honey; of vinegar in oil; gum (cummis) in myrrh; sand in bean flour; asses' milk in balsam; rock-lichen or red paint

in brine; coriander in pepper. Similar adulterations are mentioned in the commentary on the Book of Leviticus, known as "Sifra Vayikra," and which is supposed to be even older than the "Tosefta." In this commentary we find some slight variations from the above, arising from corruptions of some foreign names. In the "Tosefta Babahamma" there is mentioned the adulteration of the stalks of asparagus with stalks of fenugrek; the seeds of St. John's bread with seeds of fenugrek, and the use of vinegar with oil. The same is mentioned in the "Mekhilta," the commentary on the Book of Exodus, which is as old if not older than the "Sifra."

In ancient Greece and Rome adulteration was frequently practised. Dioscorides mentions the adulteration of opium with gum and with the milky juice of the glaucium and lactuca, which is evidently a form of adulteration similar to that mentioned in the Talmud. In Athens the adulteration of wine was so frequent that it became necessary to appoint special inspectors, whose duty it was to prevent such adulteration. History has handed down to us the proverb: "Artificial as Canthare." The origin of this expression lies in the fact that a certain Greek named Canthare, understood so thoroughly the art of imparting to new wines the flavor of age that his name became proverbial.

In Rome, Pliny tells us, the frauds practised by the bakers were very extensive. The addition of a white earth, which was obtained from a hill in the neighborhood of Naples, to the bread in order to give it weight and body, was a practice commonly resorted to. Wine, too, was badly adulterated in Rome; so much so, indeed, that Pliny states it was impossible even for the rich to obtain the natural wine of Falerno in a pure form.

It is not, however, until the time of the middle ages that we find systematic records of food adulteration. From this time likewise begins the introduction of police regulations restricting the sale of adulterated and in particular of diseased food. In England, as early as the reign of King John, a regulation, called the assize of bread, provided for the sale of bread according to certain definite weight and size.

This assize was eventually extended to include meal that had become musty, and prohibited the sale of rotten and diseased meat.

Along with the bakers, the brewers, vintners and pepperers or spice dealers were the chief malefactors, and were severely punished for their crimes. As early as 1529, official ale testers were appointed, whose province it was to test the product of the brewer before the latter could sell it. Their method of testing, according to Blythe, was certainly unique, if not accurate. The ale was spilt on a wooden seat, so common in the ale houses of that period, and the tester sat on the wet place attired in leathern breeches. If sugar had been added to the ale or beer, the tester adhered so tightly to the wooden bench that rising became difficult. The ability to rise with alacrity indicated an extract that had no adhesive properties, and hence, the absence of sugar.

In France, as well as in Germany, official recognition of adulterated food is nearly synchronous with that in England, and the special fields in which restriction was imposed are about the same. The bakers, brewers and vintners seem to have been the ones who offended most flagrantly, and the punishment imposed was correspondingly severe. The ducking stool, the stocks, the pillory, the imposition of a heavy fine, and even burning and burial alive, were forms of punishment resorted to.

In the colonial laws of this country we find references to food legislation at a very early date. Before the arrival of William Penn, that section of country now known as Pennsylvania was regulated by what are known as the Duke of Yorke's laws. In these, as early as September 22, 1676, six years before Penn's arrival, we find an act which states: "That no person whatsoever shall henceforth undertake the calling or work of Brewing Beere for Sale, but only such as are known to have sufficient skill and knowledge in the art or mistery of a Brewer. That if any undertake for victualling of ships or other vessels, or master or owner of any such vessels, or any other person shall make it appear that any Beere bought of any person within this government do

prove unfit, unwholesome and useless for their supply, either through the insufficiency of the Mault, or Brewing, or unwholesome Cask, the Person wronged thereby shall be and is hereby enabled to recover equal and sufficient damage by Action against that Person that put the Beere to sale."

In these same laws of the Duke of Yorke we find a regulation requiring packers of beef to take an oath that they will pack no goods but those that are good and sound.

After the arrival of William Penn, the Assembly which met at Philadelphia in March, 1683, provided an act regulating the size and weight of bread and of butter. Later, in 1705, an act was passed regulating the sale of liquor, which stated that "if any person within this province shall presume to sell rum, brandy or such like spirits, that is adulterated or mixed, with water or any other liquor, knowing the same to be so adulterated or mixed, being convicted thereof by one or more creditable witnesses, he or she shall, for every such offence, forfeit the said rum, brandy or spirits to be exposed to sale and pay treble the value thereof, one moiety to the support of government, and the other moiety or half to him that shall discover and prosecute the same."

Later, in 1775, we find an act regulating the sale of bread and flour, and providing a fine of £5 for the sale of either containing improper or unwholesome ingredients. In 1835, under the Inspection Laws, are regulations for the sale of flour and meal, beef and pork, salted fish, butter and hog's lard. The law of 1775 was further amended in 1854, 1858 and 1860. From this period we have quite a number of special enactments referring to adulterated drugs, candy, milk, oleomargarine, butter and cheese, unwholesome meat and vinegar. Eventually we have the general law of June, 1895, mentioned at the beginning of the lecture.

With this introductory sketch we may leave the historical development of the subject, and consider the question of food adulteration as we find it to day.

It will probably come as a surprise to many, that the tendency existing among manufacturers and dealers to-day, to produce and sell articles of food which are either below standard, or different from what they are represented to be,

is not an insignificant fact, but a condition which has developed remarkably within the past decade. If it be remembered, furthermore, that in a number of instances, the adulteration which is practised is not only fraudulent, but at the same time also a menace to the health of the consumer, it will be seen that the condition which confronts us contains the elements to create a justifiable alarm.

The cause of this remarkable state of affairs is not difficult to trace. It must be sought in the fierce competition which is so prominent to-day in all classes of trade; in the tendency of the masses to buy that which is cheap rather than that which is good; in the inability of the poor to purchase pure food at the price which is demanded for it; and lastly, in the ignorance which renders the consumer unable to discriminate between what is wholesome and what is injurious.

The extent to which food adulteration is carried in the United States is a matter of doubt. The estimates of competent authorities on the subject vary between 2 to 15 per cent. There can hardly be any question that the first figure is too low. The last is given by Mr. Wedderburn, the special agent of the Department of Agriculture, who has examined the subject very exhaustively. Good judges estimate the value of the food supply of the United States at a minimum of $4,500,000,000 annually. If we take the very conservative estimate of 2 per cent., the loss to the consumer by adulteration amounts to $90,000,000 per year. Dr. McNeal, of Ohio, estimates the annual loss to the people of the United States at 1⅛ billion dollars; and to the State of Ohio, as the result of three years' investigation, a loss of $78,000,000 annually, or $232,000 per day. It is immaterial for the purposes of this lecture, which of these figures is correct. Either amount is sufficiently large to prove that the actual money loss to the consumer arising from the purchase of food-stuffs other than they are represented to be, is so great as to merit attention at the hands of the individual, the State and the national government.

Nor does it seem that the sophistication of food is confined to any particular district. The fact that nearly every

State in the Union has either general or special laws regulating the sale of food, affords in itself sufficient evidence that these laws were enacted in answer to a crying need for them. Furthermore, the reports of the Commissioners, Boards of Health and other officers appointed to administer the laws in the various States, show that the falsification and adulteration are systematic and general throughout the country. What is true of the extent of adulteration, so far as territory is concerned, is equally true of the kinds of food adulterated. It would be difficult to find a single food-stuff requiring preparation to make it palatable, that has not been subjected to the skill of the sophisticator, or which, on investigation, will not, to a greater or less extent, disclose the hall-mark of fraud.

Several years ago the national Department of Agriculture, under the superintendence of its chief chemist, Dr. H. W. Wiley, instituted a series of investigations of the more common food-stuffs, such as molasses, sugar, honey, confectionery, canned goods, etc. Letters were addressed to prominent chemists in the States of Indiana, Nebraska, California, Kentucky, Massachusetts, Louisiana, Pennsylvania, Ohio and New York, with the request that they purchase samples of the above articles in their respective States, examine the same and report on their condition of purity. The department at Washington at the same time conducted a similar series of tests on articles of food sold in the vicinity of the capital. The results obtained from the examination of molasses and syrup are in the main a criterion of the results found with the other articles of food examined. As a rule, each chemist analyzed fifty samples, with the following results: Indiana showed 32 samples which contained tin; of the Nebraska samples, 35, or 70 per cent. contained glucose; of the California samples, 11, or 22 per cent. contained glucose; 19, or 38 per cent. of the Kentucky samples were found to contain the same ingredient. Worthy of notice is the fact that Massachusetts, the State in which the food laws have been most rigidly enforced, showed the smallest percentage of adulteration, only 8 of the samples, or 16 per cent. containing glucose; Louisiana,

the headquarters of the molasses industry, gave 16 samples adulterated, or 32 per cent.; Pennsylvania's report does not redound to her credit, as 31 samples, or 62 per cent. contained glucose; of the samples examined in Washington, of which 25 were bought in Washington and 32 in Baltimore, 14 of the Washington samples and 13 of those from Baltimore contained glucose. Furthermore, 32 of the samples contained tin and 19 copper. The samples examined in these ten sets represent the greater number of the producers to be found in the United States, and probably no better illustration could be given of the extent of food adulteration than is represented by these few figures.

The character of food adulteration goes hand-in-hand with the extent of the adulteration and the kinds of food adulterated. It is simply astounding to what extremes the rapacity and ignorance of the producer have led him in order to increase his profits. Were the adulteration entirely of such a nature that the consumer's pocket-book only was injured, it is possible that extenuating circumstances for such fraud might be found, and the offence in a measure condoned. But when substances are added to our foods which are known to have harmful effects on the human organism; when the adulteration consists of the addition of drugs and chemicals which, when taken into the system, are known to be cumulative poisons—and it has been repeatedly shown that such adulteration is practised—then we can only pray that the world at large may soon be educated up to the standard of seeing that it must, for its own protection, stamp out this evil of adulteration with every force that it can exert.

To bring this matter more clearly before you, let us leave generalities and consider in detail some of the adulterations that have been and are being practised to-day on the more common articles of food. Of these probably none are so important as the two in daily use by all classes of people of all ages, viz.:

MILK AND BUTTER.

The chief adulterant of milk, an adulterant most plentifully found, and one having the special advantage of cheap-

ness, is water. Formerly, the addition of flour and starch to milk was occasionally attempted, but it is not probable that such sophistication exists to-day in other than isolated cases. In the last few years, the tendency to add preservatives to milk has grown quite common. In fact, so prevalent has this practice become, that many State legislatures have made it a subject for legislative action, and in Pennsylvania we have a special enactment whereby it is a misdemeanor to add to milk, boracic acid salts, boracic acid, salicylic acid, salicylate of soda or any other acid, drug, compound or substance. Legislation against the addition of water is likewise general throughout the States, and special enactments, defining explicitly what shall constitute pure milk, are the rule rather than the exception. In Pennsylvania, for example, standard milk must contain 12½ per cent. of milk solids, 3 per cent. of fat, and must have a specific gravity ranging between 1·029 and 1·033 at 60° F. Under adulterated milk, there is included also milk obtained from diseased cows or from cows fed on putrid substances, the selling of such milk being made a misdemeanor and punishable.

The adulteration of butter is of so peculiar a kind and has such widespread significance, that the legislation on the subject has been undertaken not only by State legislatures, but by Congress as well. We may leave out of consideration adulteration by preservatives, such as we met under milk, since what is true of milk in this instance is likewise true of butter. Of far greater importance is the adulteration or substitution of butter, the product of milk, by the artificial product obtained from animal or vegetable fats, and known as oleomargarine, margarine, butterine, etc.

It is not within the province of this lecture to discuss, either *pro* or *con*, the question of the value of oleomargarine and similar products as food-stuffs. Much has been said and even more has been written on this topic, and I believe that I am safe in saying that to-day even experts are undecided. Whether milk fats are more digestible than animal fats, whether the germs which may remain in oleomargarine at the low temperature at which it is produced, are more

pathogenic in their nature than those which find a habitat in the cow-yard and in the stable, are not questions for us to decide. Our interest in the matter begins when there is sold, as pure butter, any oleaginous substance or any compound of the same other than that produced from unadulterated milk, or cream from the same; and here, too, our interest virtually ends. Until it is definitely proven that oleomargarine and similar products are injurious to the human organism, their sale, when sold as such, does not come under the scope of food adulteration. This fact has been taken cognizance of in our national legislation. The United States allows the sale of oleomargarine and its allies, when the seller is properly licensed and when the special laws as to branding, marking, etc., are fulfilled.

The State of Pennsylvania, however, has taken an extreme stand in the matter. By an Act of Legislature, it is a misdemeanor for any person, firm or corporate body to manufacture, sell, or offer for sale, or have in his, her or their possession, with the intent to sell the same as an article of food, any article made out of any oleaginous substance, or any compound of the same other than that produced from unadulterated milk or cream from the same, or any article designed to take the place of butter or cheese produced from pure unadulterated milk or cream from the same, or of any imitation or adulterated butter or cheese. By this law, oleomargarine and similar products, and what is known as filled cheese, viz.: cheese to which animal or vegetable fats have been added, are completely excluded from Pennsylvania.

If we examine more closely, however, we shall find that the true inwardness of this law has nothing to do with food adulteration. Below and beneath the verbiage of the enactment is the fact that the law was framed not necessarily to insure wholesome food, but to protect the large and still growing dairy industry of the State. Statistics have shown that the products of butter and cheese in the United States amounted, in 1889, to $245,000,000, or $39,000,000 more than the product of all of the gold, silver and iron mines in America. The State of Pennsylvania produces annually

100,000,000 pounds of butter, so that every individual who owns even a single cow—and of these there are many—is directly affected by the dairy question. Opposed to this is the fact that the entire oleomargarine industry is in the hands of less than twenty-five men. I believe this statement indicates with sufficient clearness that the true tenor of the law was the protection of a large number of the residents of Pennsylvania against the supposed encroachments of a few outsiders. Whether this is within the province of the State is for others to decide. It does not come within the province of this lecture.

Next in importance to the products of the dairy are those of our cereals and leguminous plants.

THE STARCHES AND VARIETIES OF FLOUR.

Fortunately for us, adulteration among these products is the exception rather than the rule, particularly in the United States. What adulteration there is consists mainly in the partial substitution of one flour or starch by another. In wheat flour, for example, in the few cases that have been reported, the adulteration consisted of damaged peas, ground rice, corn meal, and rarely the addition of alum, to increase the whiteness. Under adulteration must also be considered musty flour and flour containing dirt and smut. Buckwheat is adulterated with wheat and other flours; sago with potato starch.

With the products of flour, such as bread, buns, cake, macaroni, vermicelli, etc., the adulteration, while more frequent, is likewise not very pronounced. Bread is said to be adulterated with alum, sulphate of copper, ammonia, flours other than wheat and inferior grades of flour. It is questionable if these adulterations are practised to any extent in the United States. In England and on the Continent a number of cases are on record, in which the above adulterations were found and the offenders prosecuted.

Where coloring principles are a desideratum, the adulteration of bread, cake, etc., while not frequent, has been very marked. Possibly all of my hearers may remember the flagrant adulteration of buns and noodles with chrome

yellow which was brought so prominently to the notice of the Philadelphia community several years ago. Dr. Henry Leffmann at that time found 8 grains of lead chromate in a pound of a sample of soup noodles, placed there to give an imitation egg color, and 2 grains of the same poison in each of the tea buns tested by him. Seventy-eight cases of lead-poisoning were reported by Dr. Stewart from eating chrome yellow pound buns, sixty-four of which were directly traced to the use of chrome yellow by two bakers, in the family of one of whom six deaths occurred, and he himself was made seriously ill. Besides this coloring, macaroni has been found to contain saffron, turmeric (which is considered injurious to health), and Martin's yellow, which is poisonous. In vermicelli, pipe-clay and kaolin have been found as adulterating constituents.

In connection with the baking of bread, cakes, etc., and the presence of alum in bread, the question of alum in baking powders is of extreme importance. Alum is added to bad or slightly damaged flour by both the miller and the baker. Its action, according to Liebig, is to render insoluble the gluten, which has been made soluble by acetic or lactic acids developed in damp flour. Hence, it stops the undue conversion of starch into dextrine or sugar. It has been a popular belief for many years that the presence of alum in a baking powder acts injuriously on the human system. This belief is even held by the medical profession, and has been strengthened by the advertisements of certain baking powders which contain other substances, dwelling upon the injurious effects of alum. In contrast to these, Dr. Blyth, the English authority on foods, states that it is a question whether in the moderate doses in which alum is taken in pastry, or bread or cake, the flour of which has been mixed with alum or alum baking powder, it has the slightest appreciable influence on health. He states that he has used it in his family for years without injury, and concludes by declaring that he is decidedly of the opinion that alum in food, in reasonable quantities, is not injurious to health. Mr. C. A. Crampton, the assistant chemist of the Department of Agriculture at Washington, who has made

an exhaustive investigation of baking powders, states: "Whether the absorption of small quantities of alum into the human system would be productive of serious effects is still an open question, and one that careful physiological experiment alone can decide." Finally, Mr. Levi Wells, Dairy and Food Commissioner of Pennsylvania, in his report for 1896, which has just been published, states: "A careful study of the question leads to the conclusion that a properly compounded alum powder will perform all the desired requirements, and is no more harmful than the powders costing four or five times as much." How little weight Mr. Wells places upon the injurious properties of alum salts is shown by his recent decision on the pickle question. In this decision, Mr. Wells states that the use of "alum in pickles is not prohibited. It does not injuriously affect the same, but is added to improve the appearance and quality."

SPICES AND CONDIMENTS.

The various spices and condiments offer a very fertile field for adulteration, in that they come into the market mainly in a very finely divided form. No better example of the extent of such adulteration could be given than the bare statement of the list of adulterants that have been found in the more common spices. Nor are these isolated cases. In the samples examined, and they run into the hundreds, the adulteration is fully 75 per cent. For example, in black pepper there have been found buckwheat flour and ground hulls, cracker crumbs, Indian meal, wheat flour, charcoal, sand, bran, linseed meal, cocoanut shells, mustard husks, sawdust, ground olive stones, cayenne pepper, red clay and ship's bread. Gen. B. F. Butler has alleged that the pepper used to cure hides sent from South America to this country is washed, dried and sold as pure pepper. Mr. Wedderburn, in commenting upon this statement, aptly says: "One can imagine how they would like salt from spoiled fish or decomposed meat. This class of pepper is no better."

In cayenne pepper there has been found red lead, ground

rice, flour, salt, cracker dust, Indian meal, ship biscuit, etc. Cloves contain arrowroot, along with other substances. Cinnamon is adulterated with spent bark, gypsum, rice hulls, turmeric, browned bread and crackers. Ginger contains turmeric, cayenne pepper, mustard, inferior and refuse ginger. Of all the spices and condiments, however, mustard is king, so far as adulteration is concerned. The substances reported as having been found in it include ground yellow cakes, flour, cayenne pepper, chrome yellow, Martin's yellow, gypsum, turmeric, mustard cake colored with turmeric, diluted with starch; wheat and rice flour, weighted with terra-alba. Whole mustard contains clover seed, turnip seed and other vegetable seeds.

As regards spices, Philadelphia occupies a rather unenviable position. In 1890, Mr. Frank A. Hennesy reported that there existed in Philadelphia an industry of no small magnitude for the production of articles known to the trade as "spice mixtures;" that these were being made in a large steam bakery in Philadelphia, out of a grade of wheat lower than middlings. The process consisted in baking dough made from this wheat in the shape of biscuits and colored to meet the demands of the special spice it was intended to imitate. For the yellow of mustard, turmeric was used; for brown, the latter with Spanish brown; for black, charcoal. These biscuits were sold to the spice dealers, who "transformed" them into spices.

TEA, COFFEE AND COCOA.

Tea, coffee and cocoa are frequently subjected to adulteration, although since the enforcement of the United States tea adulteration law (1883), the sophistication of this commodity has considerably lessened. The forms of adulteration most commonly practised with tea are facing, the use of spent or exhausted leaves, and the introduction of foreign leaves, foreign astringents, such as catechu, and added mineral matter. The process called facing consists in treating the prepared leaves with mixtures of turmeric, indigo or plumbago to impart some favorite color or gloss to the leaf. Gypsum, soapstone, etc., are likewise used.

Coffee, too, is subjected to facing and coloring, particularly inferior or damaged coffee, for the improvement of its appearance and in imitation of superior grades. For this purpose there have been used yellow ochre, Silesian blue, chrome yellow, burnt umber, Venetian red, drop black, charcoal, French black, glycerine, palm oil, indigo, coal, clay, ultramarine and gypsum. More important is the substitution of coffee by the prepared root of the chicory plant, "mangold-wurzel," peas, beans and saw-dust, various kinds of seeds, cocoa husks, and in particular what is called in Germany, "Kunst Kaffee," or artificial coffee. Within the past few years, our markets have been flooded with these imitation coffees, which are composed in the main of bran, starch, flour, sugar and similar ingredients. Many of these substitutes come from abroad, but American ingenuity has likewise invented machines which enable the manufacturer of spurious coffee to turn out products so closely resembling pure coffee in appearance that its detection with the eye is difficult. Not only has ground and roasted coffee been thus imitated, but even artificial green coffee is on the market, and so close is the imitation that only experts can tell the difference. In 1891, the *Philadelphia Times* brought to the attention of its readers the extent to which this fraud was practised. It showed that immense quantities of what was known as "Java coffee compound" had been distributed throughout Philadelphia and New Jersey, and that the office of one of the manufacturers was within a block of the City Hall.

Cocoa is frequently and systematically adulterated, since it offers conditions so favorable for profitable adulteration. Mr. Spencer states that "there is probably no more misleading or abused term in the English language than the term 'soluble cocoa.' No cocoa on the market contains a very considerable percentage of matter soluble in water, unless the material so dissolved is foreign soluble material that has been added during the process of preparation." The most common form of cocoa adulteration is the extraction of the fat. It is claimed by some manufacturers that this is necessary in order to make the cocoa more readily

digestible. Whether this is the case or not, the public should be made cognizant of the amount of fat which any special cocoa preparation contains. It is impossible within the limits of this lecture to go more fully into the details of the adulteration of these three articles. The index alone to the literature of the subject covers many pages, and each article could by itself consume the time of a lecture without exhausting the subject.

LARD AND OLIVE OIL.

Of great importance to us as food-stuffs are two articles, lard and olive oil. The character of the adulteration practised with these two substances is somewhat limited; the extent of the adulteration seems to know no bounds. With both lard and olive oil, the usual form of falsification is the substitution of the oils and fats which occur in them, by other vegetable or animal oils and fats, in particular by cotton-seed oil. Besides this general adulterant, olive oil has a special adulterant in peanut oil, while lard contains the stearines and oleo-stearines obtained from beef and sheep fats. Finally, to cap the climax, it has been found that water to the extent of 20 per cent. may be worked in with lard, without causing any appreciable difference in its appearance, if an alkali such as carbonate of soda be added at the same time. The extent to which this last adulteration is practised is probably much larger than is generally supposed. The use of cotton-seed oil for the adulteration of both lard and olive oil has grown into a very extensive industry, and it is probable that 75 per cent. of the oil sold as olive oil, salad oil, etc., contains cotton-seed oil to a greater or less extent. Furthermore, it has been definitely proven that cotton-seed oil is shipped from this country to Europe, in bulk, there used to adulterate olive oil, and then returned to these shores labelled as a pure product of the olive.

MOLASSES, SYRUP, HONEY, CONFECTIONERY.

The adulteration of molasses and syrup has already been considered in the foregoing, where it was shown that the bulk of the samples examined contained glucose, or tin salts.

These latter are added for the purpose of bleaching the molasses, and are highly objectionable on account of their poisonous properties. Sulphites and hyposulphites are likewise added for a similar purpose, and are very frequently found in the light-colored New Orleans molasses which comes into our markets. Sugar is an article of food that is rarely adulterated by added matter. Occasional samples show the presence of starch or of minute quantities of ultramarine which has been added to improve the color. Several years ago, an attempt was made to adulterate cane sugar with sugar made from corn starch, but owing to the sticky properties of the latter, the method had to be abandoned. Of low grade sugars, water is the chief adulterant. The modern methods of sugar boiling permit of the introduction of considerable quantities of water without any appreciable difference in the appearance of the sugar.

Honey, like the other food-stuffs that have been mentioned, is frequently adulterated. This is true, however, only of strained honey or of comb honey packed in glass jars, it being almost impossible to adulterate honey that is sold wholly in the comb. When sold as strained honey, or as comb honey in glass vessels, the adulteration practised is of the most glaring kind. The cases are frequent where the honey has been separated from the comb, the latter placed in vessels, covered with glucose, and the mixture then sold as pure comb honey. A thick syrup of cane sugar is also used to adulterate honey, but owing to the tendency which it has to crystallize, it can be used in small quantities only.

It is difficult to say what constitutes adulteration in candy, there being no fixed standard for its composition. The usual conception of candy is a compound made up of saccharine matter, flavoring, and either with or without coloring matter. So long as any of these ingredients is not injurious to health, it can hardly be said that candy is adulterated. The cheaper grades of candy contain, as a rule, commercial glucose instead of cane sugar, starch and a gum, such as gum tragacanth. Occasionally terra-alba and injurious coloring matter obtained from coal tar have been found, but, as a rule, the principal coloring consists of an

organic dye which has no harmful properties. The following is a partial list of the substances found in 250 samples of candy examined by the national Department of Agriculture:

Sucrose, dextrose, maltose, dextrine, starch, gum, gelatine, grease, flour, copper, mineral colors, cochineal, eosin, corallin, Bengal red, fluorescin, ultramarine, turmeric, methyl orange, carmine, lampblack, Victoria yellow, magenta, orange red, aniline brown and Bismarck brown.

CANNED VEGETABLES, CATSUP, JELLIES, ETC.

Under one heading we may consider several groups of food-stuffs, which while different in composition, are alike in the form of adulteration, which is resorted to. These groups include the varieties of canned vegetables, fruit butters, jellies, preserves and catsups. The forms of adulterations, common to all of these, consist in the use of coloring matter, of imperfect vegetables or fruits, of other fruits and vegetables than those called for, of preservatives. In the case of canned vegetables, there is an accidental adulteration from the ingredients of the can, such as lead and tin, and which may, as a rule, be attributed to a lack of care in canning.

In all of the groups mentioned the adulteration practised is of the most flagrant and extensive kind. Catsups are made of skins and cores instead of the pure vegetable, then colored with a coal-tar product and loaded with salicylic acid to prevent fermentation. Fruit butters are nothing but parings and scrapings of fruit, to which glucose, starch and coloring have been added, with salicylic acid as a preservative. Jellies are made from glucose, flavored with essential oils and colored, to which salicylic acid is added. Some fruit jellies marked as pure have never seen a trace of fruit. What is true of jellies is true of preserves. Put together refuse material, the cheapest sort of glucose, some coloring and salicylic acid, and you have the composition of some of the cheaper forms of preserves that are to be found on the shelves of some of our grocery stores. Of these coarser forms of adulterations it will be unnecessary to say

even a word. They are universally recognized as unfit to be used, and every honest dealer is of the opinion that the sooner they are driven out of the market the better it will be for trade. Two special forms of what have been and still are considered adulterations, cannot be so lightly passed over. These are the use of copper salts for greening vegetables, such as peas, and the very extensive use of salicylic acid and allied products for the preservation of the vast bulk of the articles of food above mentioned. Regarding the greening of peas by copper salts, the last word has probably been said. At a conference between the officials of the State and a committee representing the Retail Grocers' Association of Philadelphia, held at Harrisburg, on April 15, 1896, Mr. Finley Acker, of Philadelphia, delivered an address on "Colored French Peas," in which he showed, to the satisfaction of every one present, that the addition of copper salts to peas, in the amount ordinarily used, could exert absolutely no injurious influence on the system.

Mr. Acker showed in detail that during the past forty years, hundreds of millions of cans of French vegetables had been eaten, and that in the entire time there had never been a single well-authenticated instance of poisoning that could be definitely traced to the minute quantity of copper used in preserving. He further showed that copper occurred naturally in bread, wheat, oats and other cereals, meat, wines, water, in the blood and in the organs of man, in quantities at times larger than are found in the peas under discussion. In his address he quoted as conclusive testimony, the investigations of eminent chemists, who subjected themselves and their entire families to a systematic diet of copper salts in their food for a period of years without noticing any injurious effects in the entire time.

As a result of the conference, Mr. Wells handed down his decision that all the department would require on French vegetables would be the distinct labelling "artificially colored," whenever coloring matter is used. This ruling has since been extended to include all canned vegetables, whether imported or domestic.

While, therefore, to-day there is a concensus of opinion regarding the non-injurious effect of copper salts when used in vegetables in judicious amounts, an entirely different view is held regarding the use of salicylic acid, benzoic acid, boracic acid and similar drugs as food preservatives. Notwithstanding the protests of some manufacturers that it is impossible for them to properly prepare their products without the use of such preservatives, it has always been the case that canned vegetables, etc., in good condition and free from added preservative, can be obtained if they are desired. Investigation has furthermore shown that, in many cases, the preservative has been added not to protect good food, but to improve that which is already decomposed and tainted.

There can be hardly any doubt in the mind of the discerning individual, after the conclusive and exhaustive researches that have been made, that the use of preservatives such as have been mentioned, and of salicylic acid in particular, in any quantity whatsoever, should be positively prohibited. More stress is laid upon salicylic acid than upon the others, since this is more commonly used. A single druggist in Columbus, O., reported that he had sold in one season over 500 ounces of the drug, all of which he felt confident had been used for the preservation of food.

It is well known to-day that salicylic acid is a powerful antiseptic. As such it retards the action of organized ferments like the yeast plant and putrefactive bacteria. It hinders and prevents fermentation, the souring of milk and the putrefaction of milk. Its action upon unorganized ferments is even more powerful. It completely arrests the conversion of starch into grape sugar by diastase and pancreatic extracts. This action is directly opposed to the process of digestion, and were there no other reason, the use of salicylic acid should be universally condemned. These facts in connection with salicylic acid have been recognized very thoroughly in legislation. The use of the acid has been condemned by most of the European countries having pure food laws. In France it is forbidden by law. In Austria, Italy and Spain it cannot be used without the danger of in-

curring a heavy penalty, and all South American States having pure food laws have absolutely forbidden its sale. The laws of many of the States forbid its use. By a decision of Mr. Wells, the Dairy and Food Commissioner, the use of salicylic acid in foods is prohibited in Pennsylvania.

I wish to call attention here to another fact in connection with the use of salicylic acid, which is of extreme importance, viz.: the sale of preservalines, preservatives, etc., under various high sounding names, intended for use in private families. A number of these, claimed to be perfectly harmless, are on the market, but actually contain salicylic acid as the main ingredient. The conscientious and careful housekeeper should put an absolute veto upon the use of any such compound. There is rarely any need for them, since when pure fruits and vegetables are used, and the proper directions for sterilizing by heat, etc., are carried out, canned or preserved goods of all descriptions can be prepared that will remain in good condition for years without the aid of any preservative.

Of the more common food-stuffs still to be considered, are:

VINEGAR, BEER AND WINE.

All three of these are extensively adulterated. With vinegar, the main form of adulteration is the addition of water and the consequent lessening of the acidity and of the total solids which a standard vinegar contains. In Pennsylvania, the standard for cider vinegar is an acidity of 4 per cent. and 2 per cent. of solids. Besides this practice, the sale of spirit vinegar, colored with caramel, for pure cider vinegar is very common, and in fact until the enforcement of our stringent law, there was very little pure cider vinegar on the market. White wine vinegar is likewise frequently a delusion. In its place there is sold the distilled vinegar obtained from grain. This grain or spirit vinegar, even when sold for what it is, is frequently adulterated by the addition of water. The vinegar law, as at present constituted, makes no standard for any vinegar other than cider vinegar, and hence it is impossible to define

what constitutes a standard spirit vinegar. This feature of the law makes the entire statute very objectionable, and it is probable that at the present session of the Legislature a new law, drafted by Deputy Commissioner Moore, of the Food Department, will be introduced to remedy this evil.

Regarding wine and beer, but little can be said at present. In this State no standards have been set up as to what shall constitute the pure article. If beer and other malt beverages should consist solely of the product of malt and hops, then the addition of burnt sugar, licorice, treacle, quassia, coriander and caraway seed, cayenne pepper, soda, salicylic acid, salt, grains other than barley malt, is certainly adulteration.

Wine has been adulterated from the very earliest times. It is hardly necessary for me to say that the same condition of affairs exists to-day. Fortification with alcohol, the use of coloring principles, the addition of acids, and even worse forms of adulteration—such as the addition of refuse matter that will ferment—are frequently resorted to. The entire subject of liquid food and nourishment offers a very fertile field for investigation by the authorities, and must eventually end in the framing of a law which will define what shall constitute adulterations in these articles.

Before bringing this lecture to a close, I trust you will allow me a few minutes for a discussion of the Pure Food Law as it exists in Pennsylvania. Nineteen months have passed since the law was framed, and in that time it has met supporters and detractors without number. Reputable merchants, as a rule, have given it their support and have endeavored to conduct their business according to its requirements. Of all the blows which have been levelled at it, possibly the worst, so far as immediate results are concerned, is the recent decision of Judge Hemphill, of Chester County, declaring the law unconstitutional. In order to appreciate this decision more thoroughly, permit me to quote a few passages of the act of June 26, 1895, entitled, "An act to provide against the adulteration of food, and providing for the enforcement thereof." Section 1 of this act reads: "Be it enacted, etc., that no person shall, within

this State, manufacture for sale, offer for sale or sell any article of food which is adulterated within the meaning of this act."

Section 2 reads: "The term food, as used herein, shall include all articles used for food or drink by man, whether simple, mixed or compound—

Section 3 reads: "An article shall be deemed to be adulterated within the meaning of this act—"

"(*a*) In the case of food: (1) If any substance or substances have been mixed with it so as to lower or depreciate or injuriously affect its quality, strength or purity. (2) If any inferior or cheaper substance or substances have been substituted wholly or in part for it. (3) If any valuable or necessary constituent or ingredient has been wholly or in part abstracted from it. (4) If it is an imitation of or is sold under the name of another article. (5) If it consists wholly or in part of a diseased, decomposed, putrid, infected, tainted or rotten animal or vegetable substance or article, whether manufactured or not, or in the case of milk, if it is the product of a diseased animal. (6) If it is colored, coated, polished or powdered, whereby damage or inferiority is concealed, or if by any means it is made to appear better or of greater value than it really is. (7) If it contains any added substance or ingredient which is poisonous or injurious to health: Provided, that the provisions of this act shall not apply to mixtures or compounds recognized as ordinary articles or ingredients of articles of food, if each and every package sold or offered for sale be distinctly labelled as mixtures or compounds and are not injurious to health."

Judge Hemphill's decision of the unconstitutionality of the law rested on Clause 2 of Section 3, which refers to the substitution wholly or in part of any inferior or cheaper substance for the food in question. The learned Judge contended that substitution was not the same as adulteration, and since there is no mention of substitution in the title of the act, the act violated the organic law of the Commonwealth, which requires the particulars of any section of an act to be nominated in the title. Unfortunately for the Pure Food Law, there is hardly any question that Judge

Hemphill is correct from the legal standpoint, and the case offers but another illustration to many that have gone before of slipshod methods of legislation notwithstanding the presence of considerable legal talent in our legislature. Unquestionably, this section of the act will require revision and amendment.

Possibly other sections may require similar treatment. For example, Section 2 states that "the term food as used herein shall include all articles used for food or drink by man. * * *" This section is a counterpart of the English law on the subject, and yet in England it has been decided that under this clause baking powders could not be included. Judge Hawkins, in rendering his decision, stated that "the mere sale of an article, not in itself an article of food, even though it be sold in the knowledge of the vender, that it is the buyer's intention to mix with it the ingredients of which an article of food, *e. g.*, bread, is to be composed, is no offence under Section 3, and it makes no difference, in a legal point of view, that when sold it is mixed with other ingredients not in themselves hurtful, some or one of which might in an unmixed state be used as articles or an article of food, if the injurious and harmful articles are so inseparably mixed and in such quantities as that the mixture as a whole forms an injurious compound which no one would dream of using as a food." Referring to the baking powder in dispute, Judge Hawkins said: "Who would venture to describe such a mixture (sodium bicarbonate, 20 per cent.; alum, 40 per cent.; ground rice, 40 per cent.) as the food of man? With equal truth might not powder composed of poison mixed with flour be called food for man because pure flour is used? Possibly it may be said that the injurious ingredients, when mixed with other materials of which an article of food is composed, become a part and parcel of such article, but that is no argument against the vender of such injurious ingredient, unless such injurious ingredient can be treated as an article of food at the time of the sale. That is the moment when the test of its character is to be applied, and if it is not then an article of food, no offence is committed by the vender of it, though the purchaser or

any one who afterwards mixes it with an article of food intended for sale, would be guilty of an offence."

This is but one illustration, but it suffices to show that astute legal minds could possibly detect other flaws in our present law. For this reason, it is well that decisions such as Judge Hemphill's should see the light of day; for, while their immediate effect is baneful, their ultimate outcome will mean the revision of the law in such a form that it will be impregnable.

Aside from possible flaws, the law as it stands has received opposition from other sources. The manufacturer, the dealer and the retailer has each, in his turn, found some clause that was obnoxious, some section that interfered with his business interests. Without going too minutely into details, it is conceded even by those who recognize the beneficial value of a pure food law for the honest tradesman, and notwithstanding the liberal policy that has been the invariable rule of the Dairy and Food Commissioner, that it is an impossibility to comply with the letter of the law in its present form. If it were the retailer only who complained, or the dealer, or the manufacturer, or any two of these, it might be supposed that any existing fault in the law would be special in its nature. The fact that the complaint is general, leads to the inference that the fault is organic.

To my mind, the inherent error of the law lies in the absence of a thought which should always be present in legislation of this kind, the underlying idea that a distinction must be made between adulteration that is the result of fraud or negligence and that which arises notwithstanding the fact that every possible precaution to prevent it has been exercised; in other words, the distinction between adulteration wilfully and deliberately planned, and adulteration the result of an accident beyond the power of man to prevent. Countries older in food legislation than we are have recognized this distinction, and have incorporated it in their laws and even in the punishment imposed for their infraction. In Germany, for example, where every detail of food adulteration has been worked out to a nicety,

and where the punishment imposed for the violation of the statutes is severe, the law distinguishes between adulteration prejudicial to health and that which is not. In the latter case, it is first necessary to establish guilty knowledge on the part of the vender before punishment can be imposed. Where substances injurious to health are used, punishment is imposed; and should death result from the use of such substances, the imprisonment may be for a term of five years. In the case, however, where the toxic nature of the substance was known to the vender, the punishment is imprisonment for ten years, and in case of the death of the user, the seller may be imprisoned for life.

After what has been mentioned, it will hardly be profitable to discuss more thoroughly our food law or its administration. The authorities, as must be plainly seen, have no volition in the matter, but are compelled to enforce the law and to prosecute adulterations under the law, as defined in the act which regulates the duties of the Commissioner. Possibly no better proof of the inadequacy of the law could be given than the fact that, notwithstanding the exceptionally humane policy of the Commissioner, and his desire to be not only just but merciful in his decisions, the law has in several cases been a positive source of injury to unintentional offenders, who desired nothing more than to be honest and conscientious in their dealings.

But little more remains to be said. As to what shall constitute the responsibility of the State and the duty of the individual must be left for a more explicit law to decide. In general, it may be stated that the State must eventually recognize that its responsibility does not end with a mere police surveillance and the means necessary to accomplish this one function. It will finally be seen that it is within the province of the State to branch out on the broader lines of educating the community up to the standard which it imposes in its laws. That this will entail expense is without question, but this is a problem that will not admit of the consideration of cost. For the proper development of a food law much is needed—a competent corps of officials; a thorough-working system; an efficient and suitably con-

structed laboratory and appurtenances for the purposes of investigation and research; the dissemination of the results of these researches, so that they reach every individual interested; all these constitute the legitimate work of the State, and should be so recognized. When this is once accomplished, and when the law is so framed that the ethical idea of a distinction between deliberate and unintentional wrongdoing is incorporated as one of its bulwarks, on that day every one will acknowledge that a pure food law has more influence in protecting the health of the community, in benefiting trade, and in inculcating the doctrines of social and moral order, which are the mainstay of the State, than has any other statute in the laws of the Commonwealth.

TRANSVERSE STRENGTH OF CHILLED CAR WHEEL METAL AS AFFECTED BY THE RELATIVE DIRECTIONS OF STRESS AND CHILL. WITH SOME NOTES ON THE CHEMISTRY OF CAST IRON.

By Asa W. Whitney, Member of the Institute,
Metallurgical Engineer for A. Whitney & Sons' Car Wheel Works.

The peculiarities of the cast iron suitable for any one class of work, notably for chilled cast iron car wheels, are inviting subjects for study, because the material is not only complex and in general sensitive to chemical and physical conditions, but also because little has been published explaining the anomalies revealed by chemical analysis.

Therefore, in presenting a novel physical feature of chilled iron, I wish to call attention to the fact that the complications of the subject have been taken into account, and that though my report deals with but a small number of test bars, none of which were analyzed, I know that they are practically of the same general class of material. That is to say, that though it is hardly possible that there are even two bars in the whole lot of identically the same analysis,

yet long experience with chemical and physical tests of this kind of cast iron, and particularly the calculated chemical composition of the cupola charge in the case of series I, assure me that the compositions are all good wheel mixtures, and that even the considerable differences shown between the two series (I and II) do not amount to a difference in kind of metal, but merely to degree in quality of the same kind of metal. The phenomena noted are therefore due to the relations of stress and chill, and, as a matter of fact, show to a considerable extent in cast iron suitable for purposes other than chilled castings (see *Fig. 9*).

In noting some of the complications referred to above, I would first remark that the element iron is usually slighted in reports of analyses of cast iron, evidently because it does not vary proportionately so much as the other elements, being usually 92 to 97 per cent. of the weight of the substance. Thus it is usually necessary to calculate its percentage by difference (100 — sum of other elements = iron), which throws an undue amount of analytical error upon the figure representing the iron. The value of very exact analyses in certain cases will be appreciated only when the meaning of chemical differences in composition has become a subject of closer study generally for practical purposes. A series of graphical tabulations, elaborated from reports of analyzed physical test bars of A. Whitney & Sons' wheel and other mixtures, by Wm. R. Webster, C.E., shows plainly the potent influence of relatively small variations in amounts of iron present.

Many other points are shown by a close study of this valuable work, though at first sight of its irregularities it would appear that no better proof need be sought to show the unreliability of chemistry of cast iron. It was this complication of the subject, particularly in hard iron, that necessitated five years of practical analysis, experiment and study on the part of the writer, previous to 1889, to get an insight into such and other fundamental principles governing the constitution of cast iron, which have made possible a very practical use of its ultimate chemical analysis. Even had the writer never justified his methods of iron mixing

FIG. 1.

FIG. 2.

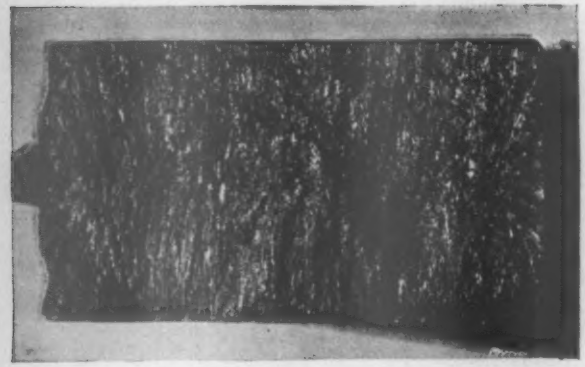


FIG. 3

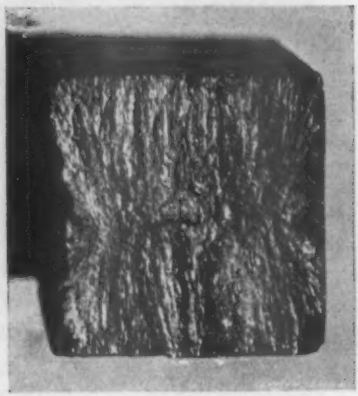


FIG 5.

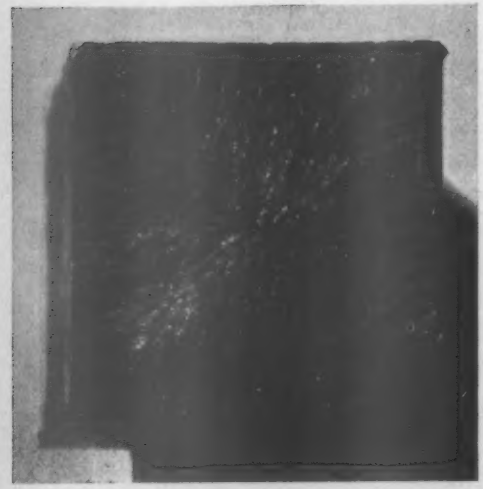


FIG 4.

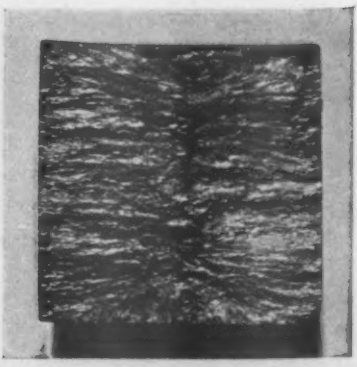


FIG. 6.

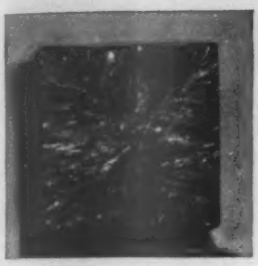


FIG. 7.

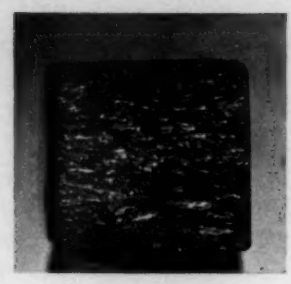


FIG. 8.

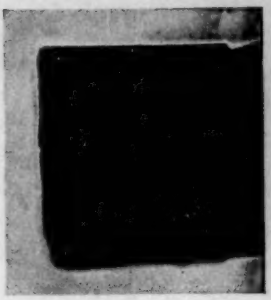


FIG. 9.

CROSS SECTIONS.

Fig. 1.—Test bar for cast-iron wheel mixture, cast in all sand mould.

Fig. 2.—Chill test of same iron, one side cast against iron block.

Fig. 3.—Test bar of same iron, same volume and area as No. 1, but chilled on wide sides.

Fig. 4.—2″ square test bar. Chilled on the four sides. Same volume and area as No. 1. Same sort of iron.

Figs. 5 and *6.*—1½″ square bars, same iron. Chilled on two opposite sides.

Fig. 7.—1″ square ingot, 4″ long. Four sides chilled.

Fig. 8.—1″ square test bar. Chilled on two opposite sides.

Fig. 9.—Strong, soft iron, 1″ square bar. Chilled on two opposite sides.

Fig. 10.—A gray pig, white in center. Ultimate composition of gray and white remarkably alike.

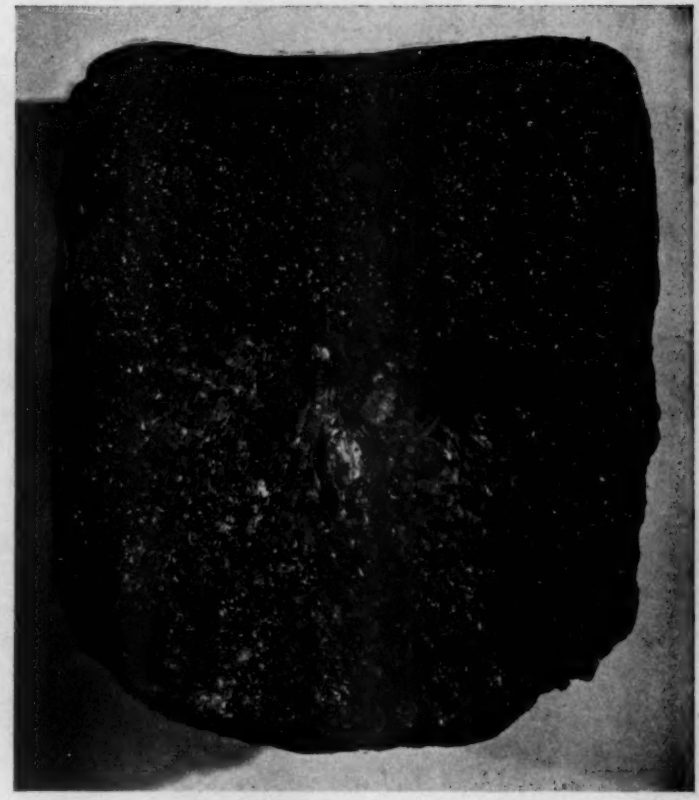


FIG. 10.

for specified quality by success and economy while working on those principles without any tabulation, these present tables are sufficient to vindicate his working theory. Beside the satisfactory and economical regulation of the quality of castings by calculations of chemical compositions of cupola charges, it naturally follows that the data and studies on compositions now collected indicate the practicability of a really accurate prediction of strength, chill and shrinkage under given conditions from the actual analysis of the casting, test piece, or even of water-chilled shots. Some success has already been attained by the writer in this direction by following out some original conceptions based on the principles already practically applied in the calculation of cupola charges for our various purposes. In the determination of strength, from the ultimate analysis, I have been aided by a rough but suggestive table, also arranged early in 1896, by my assistant, Mr. C. F. Fisher, who, though in 1890 was skeptical of the feasibility of the close application of chemistry to our cupola work, became interested in the matter as its success became apparent.

Though the least understood, the most valuable characteristic of cast iron is in reality its apparently anomalous behavior in reference to chemical composition. For instance, one finds that certain compositions, widely different in figures, are, to a valuable extent, chemically equivalent, in that they suffice to produce practically identical physical attributes in the casting. To properly grade iron by analysis in a manner equivalent to the convenient grading by fracture, this point must be appreciated. The present grading is, in general, fundamentally correct, and the chemist must learn it and then subdivide and classify it.

The above statement, however, does not contravene the fact that certain compositions, erroneously assumed to be "practically identical," are hardly to an approximate extent suitable for the same purpose. Every founder finds cases of this kind and chemists have been studying them.

In considering the above points, which have shaken the faith of many investigators in the value of the ordinary ultimate chemical analysis of cast iron, one must not lose

sight of the fact that various sorts of compositions differ not only in the *degree* to which they are affected by physical circumstances, but also are in some cases chemically affected in an *opposite manner*, which determines a reversal of ordinary phenomena, causing an appearance of liquation or segregation. But a segregated mass differs decidedly in ultimate analysis from the matrix in which it occurs; while in the cases of reversal of ordinary phenomena the differences in the ultimate constitution of the physically different parts are usually no greater than that occurring frequently in an apparently homogeneous casting. Taken alone, these peculiar compositions are inscrutable, but when tabulated along with certain other compositions in the manner of our tabulations before referred to, they will presumably be found in natural relations to compositions of more frequent occurrence.

But very possibly, before such laborious tabulation is carried much further, the developments of the rather crude formulæ, now useful to the writer in investigating chemical compositions for physical properties, particularly strength and chill, will reveal this tendency accurately.

The "opposite" chemical effect mentioned above consists in the carbon remaining in the combined state in the center of the pig or casting, while separating elsewhere in a freer form, sometimes causing almost as open a grain as a No. 1 foundry iron, but brighter. The white, sometimes very hard, crystalline spot frequently covers one-half or two-thirds of the area of the cross-section. Ordinarily, as is well known, hardening or chilling of cast iron is favored by the more rapid cooling at the surfaces, the metal becoming less dense and more graphitic toward the center.

The following are a few of these peculiar compositions:

	One Pig.		*One Pig.*		*One Pig. White and Gray Average.*
Analysis.	*White No. 866.*	*Gray No. 867.*	*White No. 53 T.*	*Gray No. 52 T.*	*No. 1878.*
Total carbon	4·181	4·775	4·255	4·339	4·066
Silicon	·161	·181	·122	·193	·183
Manganese	·609	·518	1·016	1·027	·260
Phosphorus	·328	·332	·273	·253	·037
Sulphur	·010	·010	·010	·010	·021
Iron (by difference) .	94·711	94·184	94·324	94·178	95·433
	100·000	100·000	100·000	100·000	100·000

These analyses are, unfortunately, not so scientifically accurate in the matter of sampling and in the sulphur and iron determinations as to make them of the maximum value for study and derivation of formulæ, as they were made mainly for immediately practical purposes. *Fig. 10* shows the appearance of pig like Nos. 52 T and 53 T.

The remelt of such peculiar metal shows the same phenomena as the pig, if not sufficiently altered in composition by admixture of other sorts of metal or by oxidation while melting. Sometimes even a thin casting will be found hard and white in the center, while gray or mottled outside. This is most pronounced where it occurs with silicon about 2·5 per cent., and less carbon than in the above cases.

I understand that none of the attempts to account for this by the detection of unusual elements have been successful. As an evidence that such, as well as other better known, characteristics of cast iron are due primarily to the ultimate constitution, I instance the fact that even such metal is perfectly safe to use in mixtures if the calculations are skilfully based upon the relative values of the elements as units, rather than upon the physical character which their peculiar but easily destroyed proportions have made possible. The physical characters of the component brands of a properly made mixture are "dead issues," as the creation of the desired quality in cast iron results from a combination of the elements in obedience to principles governing its ultimate constitution under the given conditions.

To those who are familiar with chemistry in other departments of art or science, it no doubt appears superfluous to insist that the qualities of charcoal iron, for instance, can be attained whenever its ultimate constitution can be properly attained, whether the elements be contained in coke iron or anthracite iron. But the superstitions of the foundry die slowly, and there is good reason in many cases, as certain qualities are very difficult to regulate. But both strength and chill depend entirely (under given conditions) upon the ultimate constitution.

37,700 lbs. tensile strength per square inch from center of half of a 2-inch square bar, 1 foot long, is the best test I

know of in coke iron, but I have no doubt it can be surpassed. That bar was cut from center of a large pig. The bar itself broke at 29,800 lbs. = modulus of rupture, 67,050, and its resilience was 186·81, which exceeds that of any iron I have tested.

It is interesting to note that this high resilience agreed, as it usually does, roughly, with the impact test of breaking the pig, by throwing violently across a heavy iron breaking-block. An ordinary pig required about five or ten times as much labor as usual to break it, and bounded up from block far more than usual. The resilience referred to in this case and in the table is obtained by the well-known formula,

$$\frac{\text{Stress} \times \text{Length}}{2 \times \text{Weight of bar in lbs.}}$$

This iron would chill from $\frac{1}{8}$ inch to $\frac{3}{8}$ inch or more, according to method of remelting. Moreover, the writer has made many mixtures of from 30,000 to 40,000 lbs. tensile strength from the poorest material. The shrinkage was low and the working qualities good, and in many cases excellent, with high transverse strength and resilience. No records of the irons and grades are referred to in repeating such results, but merely the chemical calculations and previous physical tests.

By the old way of mixing metal by estimation from physical characters, even with the aid of some partial analysis, the founder is limited seriously in the range of metal safe to use and in the range of mixtures possible to produce. Moreover, to reproduce a closely specified quality from new but apparently similar material to that formerly employed is sometimes a matter of several expensive trials.

By the new way the trial mixtures of analyzed material are made on paper and carefully studied out in reference to the foundry conditions, and adjusted until the maximum quality at the minimum cost is assured. The principles of the matter become continually more apparent, as former results are not lost, but are exceedingly valuable, though consisting merely of a record of calculated chemical cupola charges and a few simple but methodically made physical

SERIES I.

TEST BARS OF CHILLED (SOLID WHITE) CAST IRON CAR WHEEL MIXTURE. CAST IN COMPOSITE MOULDS OF IRON AND SAND. TWO OPPOSITE SIDES ONLY ARE "CHILLED." THE CUPOLA CHARGES CALCULATED AS USUAL BY A. W. WHITNEY BY REFERENCE SOLELY TO THE ANALYSES OF THE MATERIALS AND THE DAILY PHYSICAL TESTS OF THE CAST METAL.

Special Mark.	Position of Chill Crystals. (*Stress vertical.*) Dimensions. *b* = Breadth. *d* = Depth.	Approximate Hardness by Chill Tests.	Contraction in $\frac{1}{8}$ Inch per Foot.	Modulus of Rupture or Relative Trans. Strength.	Resilience—Inch Pounds per Pound of Metal (= Impact Test).	TREATMENT. *R* = "Rumbled." *H* = Heavily. *l* = Lightly.	DETAIL. Factor for Modulus. (Normal — 5·333)	Breaking Load.	Deflection.	REMARKS. Length 12″ Between Supports. Freely Supported. Cast March 19, 1896.
A	*b*, 1·470″ *d*, 1·509″	1″	·22″	52165	47·6	Not *R*.	5·3782	9700	·0718″	Cast from same hand ladle of iron at nearly same time as No. 2. Broken August 20th, after 152 days' rest in office.
Ax	*b*, 1·490″ *d*, 1·493″		·22″	48780	49·2	*R*. 2 hours *l*. along with *Bx*.	5·420	9000	·0798″	Middle of Melt. (All bars perfect but *Bx*. All heavy mixture.)
No. 2	*b*, 2·666″ *d*, 1·500″	1″	·21″	47700	49·1	Not *R*.	3·000	15900	·089″	"Regular" bar cast with *A* and *Ax*. Broken next day.
No. 3	*b*, 2·666″ *d*, 1·500″	¾″	·22″	53100	60·1	Not *R*.	3·000	17700	·088″	"Regular" bar. End of Melt. Cast with *B* and *Bx*. Broken next day.
b	*b*, 1·493″ *d*, 1·490″	¾″	·23″	33025	23·4	Not *R*.	5·504	6000	·0570″	See No. 3 Remark. But broken August 20, 1896, with *A* and *Ax* and *Bx*.
bx	*b*, 1·495″ *d*, 1·510″		·24″	26408	14·0	*R*. 2 hours *l*. along with *Ax*.	5·281	5000	·0410″	See No. 3 Remark. 2 per cent. Small in center.
Hex. No 3	4″ area Side, 1·2408″	¾″	·15″	53280	104·2	Not *R*.	2·22	24000	·111″	Same iron as No. 3, but cast in sand. Solid gray.
Average of *A*, *Ax*, *No. 2*, *No. 3* .		·94″	·22″	50436	51·5	Stress applied in the direction of chill crystals.				
Average of *A* and *Ax*		1″	·22″	50473	48·4	Stress applied in the direction of chill crystals.				
Average of *b* and *bx*		¾″	·235″	29717	18·7	Stress applied vertically to direction of chill crystals.				
Average of the four bars in the strong position differs from average of the two bars in the weak position by		Per Cent. + 25·	Per Cent. — 7·	Per Cent. + 69·7	Per Cent. + 175·4	And the Rumbling had little or no effect on this iron.				

Comparing No. 2 with average of *A* and *Ax* indicates a gain of 6 per cent. in strength and a loss of 1·5 per cent. in resilience. This may be due to the 152 days' rest, as 10 per cent. gain in strength by one year's rest has been noted by the writer in soft iron 1″ square test bars, duplicates of which without rest rumbling improved 30 per cent. in one and one-half hours.

Calculating from the above, for a 1″ square bar 12″ long (in the strong position) the breaking load for average of *A*, *Ax*, No. 2 and No. 3 = 2,802 pounds, and for average of *B* and *Bx*, also in a 1″ square bar 12″ long (in the weak position) = 1,651 pounds.

A former case (March 28, 1895,) of A. W. & S. similar wheel mixture cast and tested in same manner as above, but approximately 1″ square section in duplicate bars and measured as above, showed, in the strong position, a modulus of 46,836 pounds = 2,602 pounds on exact 1″ bar with resilience = 28·2, while duplicate in weak position = modulus 24,085 = 1,339 pounds on exact 1″ bar with resilience 7·28. The gain in strong position over weak position = 94·4 per cent. in transverse strength and 287·4 per cent. in resilience. Also 103 per cent. in calculated tensile strength, the cohesion between layers of chill crystals being 13,122 pounds and longitudinally in crystals 27,038 pounds per square inch. Direct experiment here has shown the tensile strength transversely to chill crystals to vary from about 13,000 to 18,000 pounds. No tensile test of chill longitudinally has yet been made.

Note that the maximum transverse strength of the chilled metal is nearly as high as that of the same iron cast totally gray in sand. But that the resilience is only about half that of the gray metal. This is not unusual. Crushing strength weak way = 150,000 to 200,000 pounds. No test in the strong way.

The normal size of No. 2 and No 3 bars is assumed, as they are not measured in our daily practice, but they are always a trifle under size, like the 1½″ bars, therefore results are not too high. Like hexagon gray bar, the cross-section is 4 square inches and solidity 48 cubic inches between supports.

The 1¼ square inch bar = 2·25 square inches in cross-section and resist[illegible]

TEST BARS OF CHILLED (SOLID WHI
THE CUPOLA CHARGE

Special Mark.	Position of Chill Crystals. (*Stress Vertical.*) Dimensions. *b* = Breadth. *d* = Depth.
A	*b*, 1·499″ *d*, 1·515″
B	*b*, 1·518″ *d*, 1·497″
C	*b*, 1·488″ *d*, 1·508″
H	*b*, 2·667″ *d*, 1·478″
L	*b*, 2·666″ *d*, 1·490″
a	*b*, 1·503″ *d*, 1·529″
b	*b*, 1·516″ *d*, 1·462″
c	*b*, 1·496″ *d*, 1·478″
Average of *A*, *B*, *C*, *H*, *L*	
Average of *A*, *B*, *C*, *H*	
Average of *A*, *B*, *C*	
Average of *a*, *b*, *c*	
Average of the four bars *A*, *B*, *C*, *H*, in the strong position exceeds average of the three bars *a*, *b*, *c*, in the weak position, by	Per +
Average of 9, strong position . . .	·625
Average of 5, weak position . . .	·650
	Per —

SERIES II.

IRON CAR WHEEL MIXTURE. SIMILAR IN EVERY RESPECT TO BARS OF SERIES I, EXCEPT THAT CONTROLLED BY EXPERT JUDGMENT OF FRACTURE AND OCCASIONAL PHYSICAL TESTS OF BOTH THE MATERIAL AND THE CAST METAL.

Contraction in the Inch per Foot.	Modulus of Rupture or Relative Trans. Strength.	Resilience—Inch Pounds per Pound of Metal (= Impact Test.)	TREATMENT. *R* = "Rumbled." *h* = Heavily. *l* = Lightly.	DETAIL. Factor for Modulus.	Breaking Load.	Deflection.	REMARKS.
.24″	47185	42.2	*R.* ½ hour *l.*	5.243	9000	.0684″	Length 12″ between supports. Freely supported. Cast September, 1896.
.25″	47970	42.9	*R.* 3 hours *h.*	5.292	9000	.0695″	All bars perfect but *L*. *H* and *L* are A. W. & Sons' regular form. All bars other than *L* are same sort of mixture as *H*, cast on three other days. Same letter indicates same iron dipped up from large ladle at same time by two hand-ladles and poured alike.
.23″	50010	46.3	Not *R.*	5.320	9400	.0718″	
.23″	45050	49.9	Not *R.*	3.044	14800	.0870″	Mixture for heavy wheels.
.22″	41050	36.5	Not *R.*	3.041	13500	.0800″	About 3 per cent. of minute cold shots all over. Mixture for light wheels. This is the only bar not solid white, gray center ¼″ wide.
.22″	25615	16.4	*R.* ½ hour *l.*	5.123	5000	.0479″	
.25″	26665	15.0	*R.* 3 hours *h.*	5.555	4800	.0456″	
.22″	23985	14.1	Not *R.*	5.508	4500	.0456″	
.23″+	46253	43.6	Stress applied in direction of the chill crystals.				
.24″—	47554	44.6	Stress applied in direction of the chill crystals.				
.24″	48388	43.8	Stress applied in direction of the chill crystals.				
.23″	25422	15.2	Stress applied vertically to direction of the chill crystals.				
Per Cent. + 4.4	Per Cent. + 87.1	Per Cent. + 193.5	And the Rumbling evidently had little or no effect.				

SUMMARY I AND II.

.226″	48112	47.1	
.232″	27140	16.6	
Per Cent. — 2.6	Per Cent. + 77.3	Per Cent. +183.8	Gain or loss in strong position over weak position.

TESTS OF TRANSVERSE STRENGTH OF CHILLED WHEEL IRON. EFFECTS OF DIRECTION OF CHILL. SUMMARY, SERIES I AND II.

I = A. Whitney & Sons' wheel iron. II = another founder's wheel iron. March and September, 1896

Comparisons referred to modulus of rupture or relative transverse strength. Strong position. Weak position. Stress vertical.	Series.	Number of Tests.	Special Marks.	Kind of Bar. Cross-section.	Chill Tests.	Contraction in 12 Inches.	Modulus of Rupture or Relative Transverse Strength	Weight for 1-inch Square Bar.	Resilience. Inch Pounds per Pound of Metal.	Remarks. *R* = rumbled. *h* = heavily. *l* = lightly.
				Inches. *d.* *b.*	Inch.	Inch.				
Maximum results in the strong position .	I.	4	No. 3	1⅛ x 2⅝	¾	0·22	53,100	2,950	60·1	Not *R.*
	II.	5	*C*	1½ x 1½	⅜	0·23	50,010	2,779	46·3	Not *R.*
Minimum results in the strong position .	I.	4	No. 2	1⅛ x 2⅝	1	0·21	47,700	2,650	49·1	Not *R.*
	II.	5	*h*	1⅛ x 2⅝	⅞	0·23	45,050	2,503	49·9	
Maximum results in the weak position .	I.	2	*b*	1⅛ x 1½	¾	0·23	33,025	1,835	23·4	Not *R.*
	II.	3	*b*	1½ x 1½	⅜	0·25	26,665	1,482	15·0	*R.* 3 hours *h.*
Minimum results in the weak position .	I.	2	*bx*	1½ x 1½	¾	0·24	26,408	1,467	14·0	*R.* 2 hours *h.*
	II.	3	*c*	1⅛ x 1⅛	⅝	0·22	23,935	1,330	14·1	Not *R.*
Average results in the strong position . .	I.	4 (*A. Ax* Nos. 2 & 3)		1⅛ x 1⅛ / 1½ x 2⅝		0·94	0·22	50,436	2,802	51·5	Not *R.*
	II.	4 (*A B C H*)		1½ x 1½ / 1⅛ x 2⅝		0·63	0·24	47,554	2,642	44·6	*C.* & *H.* Not *R.*
Includes one softer bar not completely chilled of a mixture for lighter wheels	I and II.	9	5 / 4	Square. / Rectangular.		0·63	0·23	48,112	2,673	47·1	—
Average results in the weak position . .	I.	2	*b, bx*	1½ x 1½		0·75	0·24	29,717	1,651	18·7	See above.
	II.	3	*a b c*	1½ x 1½		0·58	0·23	25,422	1,412	15·2	*a.* *R.* ½ hr. *l.* *b.* *R.* 3 hrs. *h.* *c.* Not *R.*
	I and II.	5	*a b c*	1½ x 1½		0·65	0·23	27,140	1,506	16·6	See above.
					Per Cent.	Per Cent.	Per Cent.		Per Cent.	
Average results in weak position being taken as 100, average results in strong position show difference by percentage of + or —.	I.	—	—	—	+ 25·	— 7·	+ 69·7	—	+ 175·4	It is evident that the rumbling has little or no effect on this solid white iron.
	II.	—	—	—	+ 8·3	+ 4·4	+ 87·1	—	+ 193·5	
	I and II.	—	—	—	— 3·8	— 2·6	+ 77·3	—	+ 183·8	
Compare the same iron as No. 3 in Series I, cast in sand in hexagon form, 4-inch area section, same as No. 3 chilled bar. (Totally gray.)	No. 3 hexagon bar. Gray.	1	Hex. No. 3	Side. 1·2408	Inch. ¾	Inch. 0·15	53,280	2,960	104·2	Not *R.*
3/28/'95, A. W. & Sons' wheel iron cast approximately 1 inch square, but measured. See *Fig. 8.*	Strong position.	1	1 in. sq.		1	—	46,836	2,603	28·2	Not *R.*
	Weak position.	1	1 in. sq.		—	—	24,085	1,338	7·3	*Gray hexagon bar of same iron = ·13-inch contraction.
					Per Cent.	Per Cent.	Per Cent.		Per Cent.	
The average results of Series II being taken as 100, the average results of Series I show a difference by percentage of + or —.	Strong.	4 to 4	See above.		+ 49·9	— 8·4	+ 6·06	—	+ 15·5	General average, 18·2 per cent. in favor of Series I.
	Weak.	3 to 2	See above.		+ 29·3	+ 4·0	+ 16·9	—	+ 23·0	All are heavy wheel mixtures. Bars totally white.

In the case of Series I the chemical composition of the cupola charge was known.

In the case of Series II the physical characters of the irons in charge were known.

In the case of Series I the physical characters of the preceding day's test bars were accurately known and the same compared with daily tests for many years. By occasional analysis of test bars and some tabulations and experience, the daily small variations are translated into chemical changes which are to be applied by slight frequent adjustments to the charge by calculation from analysis of the material at hand. A greater range of material and more changes in the constitution of the charge are allowable than in case of Series II made in the old way.

tests of the cast metal. Thus the founder's skill is not wasted on uncertain material, and he becomes interested in more exact cupola practice and careful sorting and sampling of unpromising material.

That the general principles governing the deduction of quality from the ultimate analysis of cast iron were already appreciated, and to some extent applied by the writer in 1889, is evidenced by his contribution to the subject of Car Wheel Iron, under Query No. 5, *Journal of U. S. Association of Charcoal Iron Workers*, Vol. 8, No. 3, March, 1889, from which the following quotation is appropriate: "There are, therefore, probably several proper compositions for wheel mixture, each of which depends for its physical success upon the manner of working the iron as to fuel, blast, temperature, etc., and on the relative proportion of one element to another, as well as on the actual amount of each present."

The economy and success of a proper chemical system of control of mixtures is well proven, as it has been checked by daily noting of regular physical tests for transverse strength, resilience, shrinkage and chill in the case of hard iron, and occasional similar tests of soft mixtures with tensile tests in certain cases, and constant calculation of cost. Since January 1, 1892, five regular mixtures, besides frequent special mixtures (the latter often made up at short notice), requirements in fact of a foundry melting 12,000 to 15,000 tons of iron yearly, mainly for car wheels, have been met by this system with far greater certainty, uniformity and economy than ever previously by the old method of experienced estimation of physical characters of a limited and expensive range of material. The comparison of the two series of tests I and II, as given below, is probably about as favorable as can be made for the best modern practice in the old way of making and controlling iron mixtures. Series II may be taken also as representing a quality of metal about equivalent to that attained at A. Whitney & Sons' before the adoption of the above-mentioned chemical system.

Series I represents about an average specimen of A. Whitney & Sons' wheel mixture. Its physical characters

were attained by properly calculating the ultimate chemical compositions for cupola charges, and maintained without regular analyses of the casting by translating the small daily variations in physical test pieces and castings into chemical equivalents, indicating the chemical change to be made on the charge. Thus, in spite of the usual cupola return of scrap and other adverse conditions, the charges are regulated to produce practically equivalent castings. Series I was cast of same metal as our regular test bars of March 19, 1896, with no thought of comparison with another founder's metal, but merely to experiment further on the relations of chill and stress. These bars were not broken until August 20, 1896, and though the strength was not above the average, it then occurred to the writer to ask another wheel maker, expert in the old way of regulating mixtures, to contribute to the experiment. The object was to prove the same phenomena in metal cast in the same manner, in same moulds, under other conditions of mixture and cupola practice, but well within the range of good wheel metal. The request was kindly granted, the results appearing as Series II. The results of Series I were examined by the maker of Series II after his bars were cast, but before they were shipped to the writer. They were cast about September 20, 1896, packed in sawdust to prevent any "rumbling" or "molecular annealing" effect in transit, and broken by the writer in October, 1896, on the same machine and in the same manner as employed in case of Series I.

Of course, an accurate comparison of the relative merits of the old and new way of making up cast iron mixtures can only be arrived at by taking other tests and expense into account for a year or more. That comparison has been made at our works, and shows for itself on our records with an enormous balance, both physically and economically, in favor of the new way. This improvement has been more marked since January, 1893, when the business passed entirely under the control of interests having full faith in this method.

In March, 1891, daily tests of the transverse strength of the chilled wheel metal were adopted. The bars were cast

2 inches square by 15 inches long and were chilled on the four sides (*Fig. 4*). They, therefore, presented the same appearance in the cross-section as the small ingots, 1 inch square by 4 inches long, devised by Mr. Outerbridge, and illustrated by him in an abstract of his lecture on pig iron at the Franklin Institute, February 6, 1888 (*Fig. 7*).

That is, the meeting of the crystals, or lines of chill, form a more or less distinct pair of diagonals. The transverse tests of the large bars, as shown by the steady stress of the testing machine, was nearly as erratic as had been the tests of the small ingots by hammer blows, and were of use only in connection with the gray-bar tests of same metal.

In high-chilling iron particularly, the square bar of 4 square inches sectional area, cast in sand, was found very unreliable as an aid to the development of my chemical method of iron-mixing. Therefore, in January, 1895, I obviated the trouble with hard corners by making them more obtuse and adopted a hexagon cross-section of 4 square inches area (*Fig. 1*). This gives a side of 1·24 inches width to rest on knife edges.

This bar is very satisfactory for a great range of metal, and the large amount of study and tabulation above referred to has been based upon it. I was thus encouraged to make the chilled bar more reliable, and by March, 1895, after several experiments, devised the present very satisfactory form, the results of which are worth tabulating along with those of the hexagon gray bar of same metal. By keeping the same area of cross-section as before (4 square inches), but obtained by the depth 1½ inches and width 2⅔ inches (2·67 inches), a solid white bar results even with comparatively low-chilling iron. The wide sides of this bar only being cast against a chiller, while the edges or narrow sides are in contact with sand, the lines or crystals of chill form straight parallel lines, and meet end to end from opposite sides, and the meeting line being at the neutral axis of the test bar, a slight flaw or incompleteness of chill there only slightly affects the strength. In both bars contraction is measured from small lugs, whose faces are cast against a yoke of 12-inch span—one of these lugs shows in *Fig. 3*.

All bars are cast on end, and the gray bars are gated at the bottom.

No change was made in the form of chill tests, which are 2½ inches x 1½ inches x 6 inches, the narrow edge, 1½ inches x 6 inches, being exposed to the iron chiller. *Fig. 2* shows the average chill test of such wheel metal as otherwise shown in *Figs. 1, 3, 4, 5, 6* and *8*.

The fracture of these probably shows a slightly higher chill than the same iron cast in the slightly different form of chill tests referred to in Series II.

Contraction is measured from small lugs cast on a corner of hexagon gray bar and on the narrow side of the rectangular chilled bar. The outer faces of these lugs are smooth, as they are cast against a cast-iron yoke protected otherwise by sand from the heat of the metal.

The 1½-inch square bars were cast in same moulds as the regular flat-chilled bars, but from a 1½-inch square pattern, in order to show the difference in strength of the two positions, merely by comparison of the breaking stress. For rough comparison this does very well, as when strained across the chill they break at 4,000 to 6,000 pounds, while duplicates broken by a stress in the direction of chill crystals require 9,000 to 11,000 pounds. If the regular flat bar were broken by placing it edgeways, it would not stand over 16,000 pounds, even in the case of a metal like No. 3, which, broken flat in the strong position of chill, required 17,700 pounds. If the strength were the same in the other direction, 30,100 pounds would be required to break it. Our testing machine not conveniently taking bars of this depth, 2⅜ inches, the small square bars were more convenient.

Some rather imperfect tests of the crushing strength of such chilled iron show 150,000 to over 200,000 pounds per square inch in what I presume is the weak way. I know of no tests made on the ends of the crystals such as the position of load on tread of a wheel. I believe it is much over 200,000 pounds, probably 300,000 pounds at least per square inch.

Tensile strength tests in the weak way agree with a rough calculation from the transverse strength in the weak

way, being 13,000 to 18,000 pounds per square inch. In the strong way the tensile strength is probably not less than 25,000 pounds.

Note the value of watching the resilience to compare irons of the same strength for a steady load.

The wide differences here shown in strength and resilience between duplicates or similar bars of chilled iron practically equivalent though not necessarily alike in composition, broken in one case by a stress at right angles to lines of chill, and in the other by a stress in same direction as lines of chill, are therefore mainly, if not wholly, due to the relative directions of stress and chill. It will be more accurate to understand the word "chill" in the caption of this paper as meaning "the direction of the most rapid dissipation of heat." The physical effect depending upon the composition as well as upon the rapidity of the dissipation, the result is not always totally white iron.

It is to be hoped that the presentation of these facts will lead to further investigation of the subject, as the matter has a bearing upon the selection of proper forms and sizes of test bars.

The transverse strength is represented in this table by Modulus of Rupture, as by that means bars of different dimensions can best be compared.

For any bar of rectangular cross section the formula is

$$\frac{3}{2} \times \frac{Wl}{bd^2} = \text{modulus of rupture.}$$

Here W is stress; l, length; b, breadth; and d, depth, of test bar. By dividing the modulus in each case by 18 (the factor for a 1-inch square bar 1 foot long), the strength of such bar is shown, assuming, of course, the same grain and density as that from which the modulus was calculated. Note how reasonably close the agreement is in spite of the variations from 1 inch square to $2\frac{3}{8}$ inches x $1\frac{1}{2}$ inches in size cast. In less homogeneous metal, and particularly in gray iron, the agreement is, of course, far less close in modulus calculated from different sizes.

Some of these bars were "rumbled" to see whether in

such hard white castings any change in strength would result. In one former case of two 1½-inch bars, which were not cast under the writer's immediate supervision, nor measured, though cast approximately 1½ inches square like those in these series, the rumbling apparently caused 48 per cent. gain in strength, both being reported as broken in the strong position. This case was reported by the writer to Mr. Outerbridge, of Wm. Sellers & Co., in July, 1896, as showing an increase of strength by rumbling even in such iron; but evidently there is an error in that case, as no decided effect is shown in either of the present series.

Mr. Outerbridge has demonstrated the gain made by rumbling in the strength of gray iron bars, and my few experiments agree with his in general. But this uniform white iron is apparently little affected, if at all. It is also the fact that certain strong very homogeneous gray compositions gain less in rumbling than ordinary mixtures similarly cast. But further tests on this point are needed in chilled iron.

Another point of interest is the fact, that it is proven possible to cast a high-chilling iron in such form as to have nearly or quite the same modulus of rupture, whether cast in sand so as to be totally gray, or cast of the same volume between "chills" or iron sides of mould, giving a test bar of a less depth, so as to be totally white. Compare bars No. 3 (Series I) and No. 3 hexagon (*Figs. 3* and *1*). This comparison agrees with our regular tests of wheel metal since the writer devised a proper cross section and method of casting test bars for hard iron.

NOTE IN REGARD TO ILLUSTRATIONS.—The differences in shade of the various white iron sections is rather greater than natural because of the difficulty of photographing such surfaces to bring out detail. The slightly oxidized surface of No. 4 allows the detail to be reproduced with accuracy. The minute white spots in No. 10 are the brilliant reflections from graphitic scales, not from white iron. This is noted in the description of plate.

CHEMICAL SECTION.

Stated Meeting, held January 19, 1897.

DR. JOS. W. RICHARDS, President, in the chair.

THE WETHERILL MAGNETIC CONCENTRATING PROCESS.

BY H. B. C. NITZE, E.M.

This process was first described by Mr. H. A. J. Wilkens and myself, in a paper entitled "The Magnetic Separation of Non-magnetic Material," presented at the Pittsburgh meeting of the American Institute of Mining Engineers, in February, 1896, and since then published in the *Transactions* of that society. Those who may be more especially interested are referred to the above paper, as it has dealt with the subject somewhat more exhaustively than it is practicable to do here.

It is a process for separating various mineral and chemical substances, of such feeble magnetic permeability, that they have been heretofore generally considered as non-magnetic, from one another and from such accompaniments as are absolutely inert, by means of powerful and specially devised electro-magnets.

The substances that have been found capable of being so attracted are most all of the minerals containing iron and manganese, either alone or in combination; and, likewise, the chemical salts of these metals, either alone or in combination.

Among the minerals are: hematite, limonite, siderite, chromite, menaccanite, rutile, franklinite, pyrolusite, psilomelane, tephroite, rhodonite, garnet, hornblende and many others.

None of these minerals or salts is attracted (in the ordinary sense of being lifted) by the strongest hand magnet or by electro-magnets of equivalent power.

The metals iron, nickel, cobalt, and the minerals magnetite (Fe_3O_4) and pyrrhotite (Fe_7S_8) are the only substances that are magnetic in this ordinary sense, and the only ones which are capable of being separated by the various electro-magnetic machines that have been invented prior to the Wetherill machines, such as the Edison, Wenström, Ball and Norton, Conkling, Buchanan, Payne, Chase and other magnetic separators.

It is true that separations have been made of such minerals as red hematite, limonite, siderite and franklinite on some of the above types of machines, but it has invariably been accomplished only after a preliminary conversion of the iron component to its magnetic oxide or artificial magnetite, by means of roasting in an oxidizing or reducing atmosphere.

However, while these minerals and salts are not attracted by the ordinary magnetic powers sufficiently to render their separation possible, it has, nevertheless, been long known in the science of physics that all matter is affected in some way by a magnet.

Coulomb was the first physicist to announce that not only iron, nickel and cobalt, or certain mixtures of these metals with others, were influenced by a magnet, but also that small needles of all other substances, metallic, mineral or vegetable, oscillated under the influence of strong bar-magnets, like small magnetic needles. He, however, erroneously interpreted that this action was due to the universal presence of iron, in quantities so small as to defy detection by the most refined chemical analysis, and did, therefore, not consider that it was a general property of matter in itself to be magnetic.

Nearly twenty years later, in 1824, Becquerel, who had the advantage of utilizing electro-magnets, invented, since Coulomb's time, by Oersted, discovered the repulsion produced by the poles of a magnet on bismuth.

In 1846, Faraday published the results of his very interesting and exhaustive experiments, carried on with the most delicately arranged physical apparatus, showing that all matter, solid, liquid and gaseous, was magnetic; *i. e.*, either

attracted or repelled by the poles of a magnet. He accordingly made the division into paramagnetic and diamagnetic substances, the former including those attracted, and the latter, constituting by far the greater class, those repelled.

He gave the following lists:

Paramagnetics.—Iron, nickel, cobalt, manganese, chromium, cerium, titanium, palladium, platinum, osmium.

Diamagnetics.—Bismuth, antimony, zinc, tin, cadmium, sodium, mercury, lead, silver, copper, gold. arsenic, uranium, rhodium, iridium, tungsten.

Uranium was later found to be paramagnetic (by Verdet); and almost all amorphous and organic substances belong to the diamagnetic class.

The paramagnetic substances may again be subdivided into such as are highly magnetic and such as are only feebly so.

The first class is completed with the substances iron, nickel, cobalt, magnetite and pyrrhotite. It is with the second class that we are especially concerned here.

The knowledge of the paramagnetic property of many substances has been of great scientific interest since the time of Faraday's demonstration.

In 1871, Fouqué, and since then Doelter and other mineralogists, have made use of this knowledge to some extent in the mineralogical laboratory.

But it remained for Mr. J. Price Wetherill, of South Bethlehem, Pa., to design magnets capable of producing a sufficiently concentrated field to make practical the separation of these feebly paramagnetic substances on a commercial scale. Mr. Wetherill, who is the general manager of the Lehigh Zinc and Iron Company, was led to this result in his endeavor to improve the grade of the zinc ore of Sussex County, N. J., used for the manufacture of spelter.

This ore is a crystalline granular aggregate of franklinite (FeO, ZnO, MnO) (Fe_2O_4, Mn_2O_4), willemite (Zn_2O, SiO_2) and calcite, with smaller amounts of zincite (ZnO), fowlerite (MnO, ZnO, SiO_2), tephroite (Mn_2O, SiO_2), and garnet.

It was the object to obtain the zinc-bearing minerals willemite and zincite as free as possible from the franklin-

ite, garnet, tephroite and fowlerite, the iron- and manganese-bearing minerals, as the presence of the latter is fatal to the direct metallurgical production of zinc.

After repeated and painstaking experiments, Mr. Wetherill finally succeeded, in the latter part of 1895, in accomplishing this result to perfect satisfaction, and patents have since been granted in the United States, Canada, England,

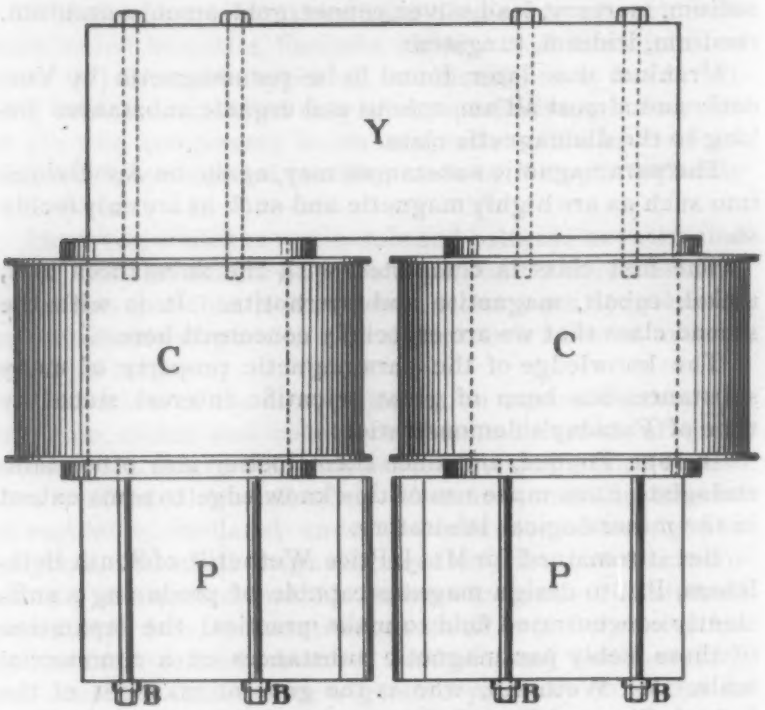


FIG. 1.—Plan of Wetherill electro-magnet.

Germany and other European countries, for the method of, and apparatus for, separating paramagnetic substances of very low magnetic permeability or susceptibility.

The accompanying illustrations show the form and arrangement of the magnets, as well as the principal features of the mechanisms for effecting the separation of substances subjected to their influence.

The electro-magnets are arranged in the general form of a horseshoe, as shown in plan (*Fig. 1*), and consist of five parts, made of soft forged iron; two cores and bobbins *C*, joined together by a yoke *Y*, and having attached to each of their other faces, by means of brass clamps *B*, a pole-piece *P*, as shown. The yoke is 31¼ inches long by 10⅜ inches wide by 2½ inches thick. The cores are 12½ inches long by 10⅜ inches wide by 2⅝ inches thick, made rectangular in cross-section, with the long edges rounded to a radius of one-half the thickness. These cores are wrapped with nineteen layers of No. 5 insulated copper wire, making 915 ampère-turns. The pole-pieces are 15½ inches long by 10⅜ inches wide by 2½ inches thick, and are tapered at the free ends at

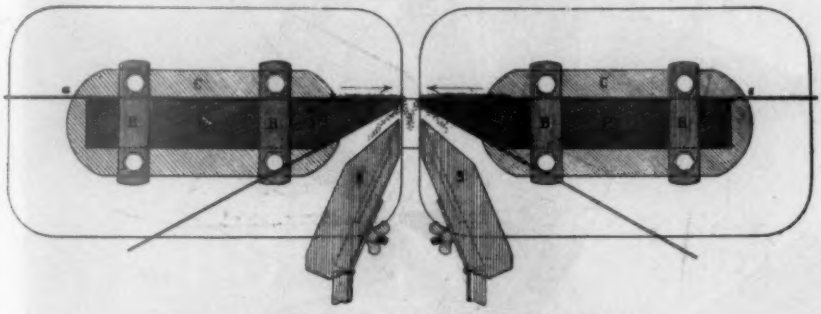


FIG. 2.—Vertical view of horizontal magnet type.

an angle of 30°, the points being rounded. The total weight of this magnet complete is 1,259 pounds.

The mechanisms for effecting the separation of minerals are of two principal types, as shown in the drawings, representing vertical views (*Figs. II* and *III*).

(1) The horizontal magnet type (*Fig. II*) in which the material is fed by means of hoppers, in a thin layer on canvas belts *a*, revolving in the directions shown by the arrows about each pole-piece *P*, and is delivered directly into the opening between the two pointed pole-pieces. Two shutters *S*, made of brass and of the same width as the pole-pieces, are situated one beneath the point *T* of each pole; they are adjustable so that the magnetic particles, which adhere slightly to the belts as they round the pole-points,

are carried to one side by the moving belts, while the non-magnetic particles fall vertically in the central space between the two shutters.

The result desired can be regulated by changing the position of the shutters, the speed of the feed belts, the distance between the pole-points, or the ampèrage of the electric current through the coils.

(2) The inclined magnet type (*Fig. III*) in which the material enters on the feed belt *a*, revolving about a brass roller *R*, and is delivered in close proximity to the space between the poles. The magnetic particles are withdrawn and lifted up into the highly intensified field existing at this point, and they are removed by the horizontal belt *b*, revolv-

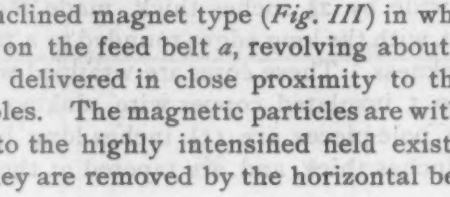
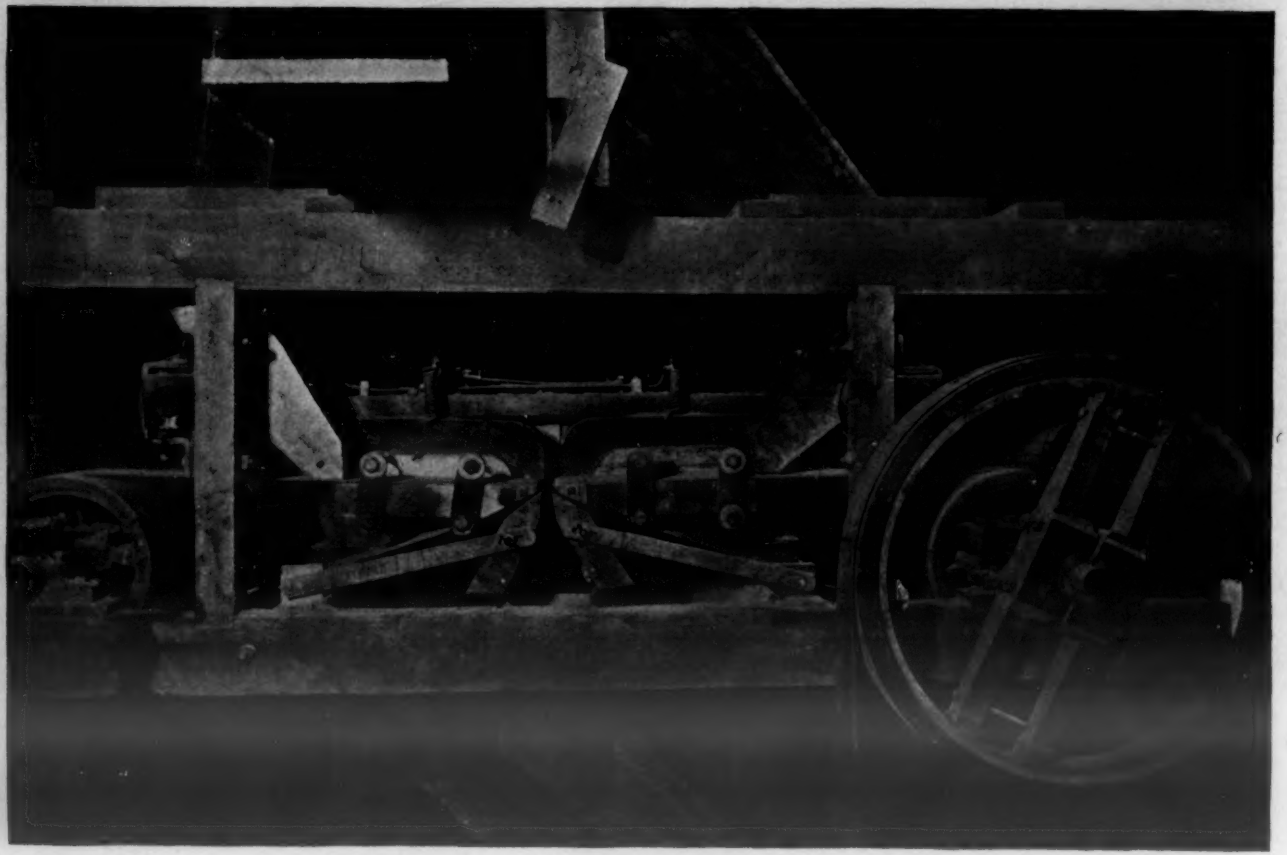


FIG. 3.—Vertical view of inclined magnet type.

ing around the lower pole point in the same direction as the feed belt; while the non-magnetic particles fall vertically from the brass roller. The revolving belt *d* around the upper pole simply serves the purpose of keeping that point brushed free from magnetic particles that would otherwise have a tendency to stick to the bare points, and ultimately choke the opening.

The intensity of the magnetic attraction can be accurately adjusted by changing the distance between the poles, the distance of the brass roller from the poles, or the ampèrage of the electric current.

The question of paramount interest is: How are these magnets capable of effecting a separation that has not been



FLAT MAGNET CONCENTRATING MACHINE IN THE PLANT OF THE STERLING IRON AND ZINC COMPANY, AT FRANKLIN FURNACE, NEW JERSEY.

practicable heretofore? How is it that substances possessing such infinitesimal magnetic permeability, that they have been commonly considered as non-magnetic, are attracted here, and actually lifted by the poles of the magnets?

The answer lies in the extremely condensed magnetic field at the pole-points, which is produced by means of the correctly proportioned cores, yokes and pole-pieces employed, and especially by the tapering ends of the latter. These ends being of less sectional area than the magnet cores, a vast number of magnetic lines are forced through and across the points.

The amount of ampèrage necessary to generate these lines in sufficient number is comparatively small. The magnetizing power of a magnet may be attained either by increasing the ampèrage of the current, or by increasing the ampère-turns, *i. e.*, the number of turns of the coil on the core, the one or the other of these functions remaining constant.

In the Wetherill magnets the latter fact is taken advantage of, and with 915 ampère-turns of No. 5 wire the quantity of current or ampèrage is reduced to an economic minimum.

The No. 5 wire is capable of carrying a current of 25 ampères, but this quantity is rarely necessary for most minerals.

For instance, limonite and pyrolusite, which are perhaps among the most stubborn of the feebly magnetic minerals, require from 10 to 20 ampères; red hematite and garnet are usually attracted with from 4 to 8 ampères; and franklinite and siderite with as low as 1 to 4 ampères.

The amount of voltage is an inconsequent factor, depending solely on the size and length of wire and the number of ampères used; *i.e.*, it represents the pressure requisite to drive the necessary ampèrage through the magnets. For coils wrapped with No. 5 wire the voltage is equal to about twice the number of ampères used; *i. e.*, the resistance is 2 ohms; for coils wrapped with No. 10 wire the resistance is 5 ohms.

To illustrate the intensity of the magnetic field it may

be mentioned that the current of a single bluestone cell (such as is used in telegraphy) is usually too powerful to permit of a satisfactory separation of the highly magnetic substances magnetite or pyrrhotite, the particles adhering to the points so tenaciously that the moving belts are incapable of pulling them off. For this purpose it is found best to reduce the strength of the current by means of resistance coils.

The ability to delicately adjust the magnetic intensity of the field permits, in many cases, the successive isolation of several products, showing a slight difference in permeability from a mixture containing the same. For instance, in the New Jersey zinc ore, franklinite can first be separated at 1 to 3 ampères, and then the garnet at 4 to 8 ampères.

This brings up the interesting question of the possibility to tabulate the minerals in distinct groups capable of being magnetically separated from one another, *i. e.*, in the order of their relative attractability. It is, however, a matter of very considerable difficulty to do this accurately, for the reason that the magnetic permeability of each mineral, in itself, is subject to wide variations; for instance, some particles of franklinite will be attracted at 1 ampère, while others will require as high as 4 ampères; some garnets will be lifted at 3 ampères, and others not until 6, 7 or 8 ampères are reached.

Nevertheless, various attempts have been made in the past by physical investigators, with more or less success and reliability of results, to determine the magnetic permeability of substances, and it may be of interest to give some of their determinations.

Delesse (*Annales des Mines*, IV Ser., Vol. XIV, p. 429) gives, among many others, the following comparative values, taking the magnetic attractability of steel at 100,000.

Magnetite	65,000
Siderite	120
Hematite	93 to 43
Limonite	72 to 43

Plücker (*Pogg. Annalen*, Vol. LXXIV, 1848) gives, taking metallic iron at 100,000:

Magnetite	40,227
Red hematite	134
Hydrated ferric oxide	156
Proto-sulphate (vitriol) of iron	98
Pyrite	150
Hydrated Mn_2O_3	70
Mn_3O_4	167

These results verify one important point, namely, the undoubted existence of a wide gap between the strongly and the weakly magnetic substances, according to which the paramagnetics are divided into two classes, as mentioned in the beginning of this paper.

The accuracy and value of the figures, otherwise, is extremely doubtful, and in some instances they are known to be absolutely erroneous and misleading, so far as experience with the Wetherill magnets goes. A striking instance of discrepancy is furnished by pyrite and iron vitriol, the former of which Plücker rates at 150, and the latter at 98. Yet the fact is that iron vitriol is attracted with ease at 8 ampères, while iron pyrites is the only iron-bearing mineral that does not, so far as present experiments have gone, come within the attracting limit of the magnets at all, although it is still hoped that it will be possible to further increase the intensity of the field by which it will be made effective upon a wider range of minerals than has been successfully treated so far, including iron pyrites.

Again, whereas Plücker places the permeability of the manganese salts not far from, and even below that of pyrite, their attractability is, in reality, far greater. It is, indeed, a curious and interesting fact that the manganese salts are, as a rule, more magnetic than the corresponding iron salts; for instance manganous sulphate (c. p.) requires only 1 ampère, while ferrous sulphate (c. p.) requires 8 ampères to be attracted.

It does not appear then that the magnetic permeability necessarily depends upon the amount of iron in a substance, or upon the chemical condition of that iron in a ferrous state, as has been thought by many. But how is this property of matter best explained?

Without here desiring to enter into a discussion of the

theories concerning the magnetic properties of matter, it may be stated briefly that, in view of existing facts, the magnetic molecular theory seems the most satisfactory to us. This theory accounts for the magnetism of bodies by the existence of magnetic molecules and explains the variation of permeability as due to the arrangement and structure of these molecules.

The ratio of the sum of the volumes of the magnetic molecules to the entire volume of a body is the magnetic density of that body. It is upon this that the capacity of a body for magnetism seems to depend, and it has been shown to vary with the temperature and other physical and chemical conditions.

In conclusion, I will give some actual results obtained in concentrating different ores by the Wetherill process:

ZINC ORES.

From Franklin, N. J.

	Percentage by Weight.	ZnO Per Cent.	Fe Per Cent.	Mn Per Cent.
Original ore	—	31·09	20·34	9·34
Franklinite, garnet, etc. (magnetic heads)	56	24·38	35·50	13·62
Willemite and zincite (non-magnetic tails)	28	60·00	1·50	6·10
Calcite (non-magnetic tails)	16	4·00	—	—

From Austinville, Wythe County, Va.

	Percentage by Weight.	Fe Per Cent.	Zn Per Cent.
Original ore	—	18·60	29·57
Limonite (magnetic heads)	33	49·45	5·58
Calamine (non-magnetic tails)	67	3·41	41·40

RED HEMATITE IRON ORES.

(From the Birmingham district, Alabama.)

	Percentage by Weight.	SiO_2 Per Cent.	Fe Per Cent.
Original	—	27·14	45·32
Magnetic heads	49	12·29	56·47
Non-magnetic tails	51	41·41	34·60

(From the Pewabic Mine, Michigan.)

	Percentage by Weight.	SiO_2 Per Cent.	Fe Per Cent.
Original	—	43·49	37·87
Magnetic heads	37	7·76	63·55
Non-magnetic tails	63	64·11	23·05

BROWN HEMATITE ORE.

(From Iron Gate, Va.)

	Percentage by Weight.	SiO_2 Per Cent.	Fe Per Cent.
Original	—	31·29	43·98
Magnetic heads	63	11·24	51·04
Non-magnetic tails	37	66·00	31·74

SILVER-LEAD ORE.

(From Monterey, Mex., consisting of galena in a limonite gangue.)

	Percentage by Weight.	Ag, ozs. Per Ton.	Pb Per Cent.	Fe Per Cent.	SiO_2 Per Cent.
Original ore	—	6·41	12·04	35·42	12·68
Magnetic heads	81	0·90	2·90	43·00	14·10
Non-magnetic tails	19	29·90	51·00	3·10	6·60

MANGANESE ORE.

(From Cave Spring, Ga.)

	Percentage by Weight.	SiO_2 Per Cent.	Mn Per Cent.
Original	—	43·00	28·78
Magnetic heads	52	20·85	40·91
Non-magnetic tails	48	67·20	15·54

Among the materials, besides those mentioned above, which have been separated successfully, are:

(1) A mixture of apatite and rutile, occurring in a deposit near Charlottesville, Va.

(2) Monazite sand from North and South Carolina, from which rutile and garnet were completely removed.

(3) Garnetiferous rocks and schists, from which it was desired to obtain the pure garnet.

(4) Garnetiferous copper ore from Mexico.

(5) Corundum ores, from which garnet and other deleterious ferruginous minerals were to be removed.

(6) Ores containing siderite, as in cryolite from Greenland, and the foreign zinc-blende ores.

DISCUSSION.

PROF. F. LYNWOOD GARRISON:—For the past three or four years a magnetic process for the concentration of copper and zinc ores (sulphides) has been in operation at Pitkäranta, Finland.

The ores used for this purpose are so lean, and mixed with so large a proportion of worthless material, that they cannot be worked by the ordinary methods of concentration and smelting. They are essentially mixtures of pyrite, chalcopyrite and zinc-blende, often associated with magnetite.

This lean copper ore, which, under ordinary circumstances, would be thrown away, containing about 1 per cent. copper, is crushed by ordinary Blake crushers and then granulated by rolls to a size of about 0·75 millimeters.

It then passes into roasting furnaces. The ore is thus gently roasted, which is a delicate operation, as the temperature must be very carefully regulated. The copper ores appear to require a lower temperature for roasting than the zinc ores, in order to render them magnetic; more or less difficulty has been experienced with the zinc-blende in this respect. When the ore comes from the furnace it is red-hot and glowing; when cold, it is passed by mechanical means to the magnetic separators, which are constructed with the special view of concentrating such magnetic material.

It is claimed that in this way from 70 to 80 per cent. of the copper in the ore is separated out, the refuse containing only about 0·20 per cent. copper. At Pitkäranta, about 600 hundred-weight of ore is treated in twenty-four hours, or about 1 ton per hour.

The results obtained with the concentration of zinc ores have not been so satisfactory, and the work on them is still in an experimental stage. The difficulty appears to be in the roasting, the proper conditions for which do not seem to be entirely, as yet, understood.

MR. NITZE:—Prof. Garrison's description of the magnetic concentrating process as applied to copper and zinc ores containing pyrite, at Pitkäranta, Finland, is very interesting, and corroborates the fact which I brought out in the beginning of my paper, namely, that apparently non-magnetic minerals have been separated on magnetic machines of the ordinary types, but only after a preliminary roasting of the material in order to render it artificially magnetic. It appears from the description that the roasting at Pitkäranta is carried on in a simple oxidizing atmosphere. No mention is made of the addition of coal, carbon, or a reducing gas to the charge. Therefore, the idea aimed at is evidently the conversion of the pyrite into pyrrhotite (the magnetic iron sulphide), by driving off a portion of its sulphur; the roasting must be arrested just at the point where the correct amount of sulphur has been eliminated, and it is for this reason that the operation becomes a most delicate one. If it be carried beyond this point the material will again become non-magnetic to the ordinary magnets. At the best, the uniformity of magnetization of the roasted product must be imperfect.

It must also be considered that, naturally, a partial concentration of the copper in the ore is effected by the roasting operation alone, the weight of the total mass being reduced by the amount of sulphur driven off.

Regarding the conversion of pyrite into pyrrhotite, it may be mentioned that Eustis and Howe (*Trans. Amer. Inst. Mining Engineers*, Vol. X, p. 105) in 1882 suggested the reduction of iron and nickeliferous pyrite to the magnetic subs[illegible] phide, but the delicacy of the operation deterred its pr[illegible] application.

Mr. G. G. Convers, superintendent of t[illegible] and Iron Company, South Bethlehem [illegible] made similar experiments on magn[illegible]

tained in a mixture of blende, pyrite and gangue from the Arminius Pyrite Mine, Louisa County, Va. He roasted the material to just the exact point to make pyrrhotite, but he found the operation such an extremely delicate one that he concluded it could not be carried out on a practical scale.

Besides the above, there are others who have experimented in the same direction and with similar results, apparently demonstrating the impracticability of such a delicate roasting operation; and it seems, therefore, the more remarkable that it should be practically successful at Pitkäranta.

However, if the roasting be carried still further, so as to drive off all of the sulphur (dead roast), converting the pyrite into Fe_2O_3, and the operation be completed in the presence of a reducing atmosphere, such as can be attained by the admixture of carbon in the charge, so as to reduce a portion of the Fe_2O_3 to FeO, the ferruginous material will then be in the condition of artificial magnetite (Fe_3O_4), which can be separated on the usual types of magnetic machines.

The great objection to such a magnetizing roasting, aside from the additional cost of the same, is that it is never perfect; the probabilities are that there will always be some particles which have not become magnetized, and will therefore pass into the tails in the process of concentration.

This disadvantage is eliminated in the Wetherill process, where any previous *magnetizing* roasting becomes not only superfluous, but undesirable, inasmuch as the magnetic permeability of Fe_2O_3 is sufficient to cause its attraction and removal in the highly condensed field of the magnets. In pyritic ores, therefore, the only operation necessary would be a simple dead roast, which can be easily and perfectly attained.

Mr. —— (a visitor), in reply to an inquiry by Dr. Wahl, whether the fine sizes of iron ores produced in concentration could be utilized in the furnace, said that this difficulty had been well overcome, as was demonstrated by the successful and practical use of such fine ores in the blast furnaces of the Lackawanna Iron and Steel Company, at Scranton, Pa.

Lehigh Zinc. (about) 1893. pyrite conc.

Stated Meeting, February 16, 1897.

SOIL FERMENTS IMPORTANT IN AGRICULTURE.*

By Harvey W. Wiley,
Chief of the Division of Chemistry, Department of Agriculture,
Washington, D. C.

Introductory.—Soil ferments important in agriculture are those which help to make the soil from original rocks and those which are active in preparing the food of plants for absorption and assimilation. The old idea that the soil is an inert mass of mineral matter has given way to the new conception of the soil as a living organism. The parts of the soil which are not endowed with life at the present time have their highest significance as the environment of the living organisms which they contain, and which they may help to nourish. The plant which forms the growing crop receives its nourishment through the media of the air and soil, but this nourishment must undergo a process of digestion, similar to that suffered by the food which nourishes animals, before it becomes available as plant food. Indeed, the purely mineral, inorganic foods of plants are probably not always absorbed as such, and must undergo a decomposition before they are assimilated. A striking instance of this is shown in the case of silica, an important plant food and a type of inert mineral matter. Silica is highly insoluble and apparently the least suited of the mineral constituents of the earth to enter the vital organism of the plant. Yet not only do we find it in the tissues of the mature plant, but also, strange to say, in the greatest abundance in those parts of the plant organism—viz.: the leaves—most remote from the sources of supply. It is evident from this that the highly insoluble silica of the soil must undergo a

* Abstract of a lecture delivered before the Chemical Section of the Franklin Institute, February 16, 1897.

complete solution in order to be carried by the juices of the plant through the network of cellular tissues, to be finally redeposited in the leaf.

The part which soil ferments have played in the formation of arable soil from the original rocks is not thoroughly appreciated. The naked rocks of high mountains comprise mineralogical types of the most varied nature, viz.: granite, porphyry, gneiss, mica schist, volcanic rocks and limestones of all varieties, and all these have been found to be covered with a nitrifying ferment which is doubtless extremely active in producing incipient decay. At the high altitudes in which these observations have been made, the activity of bacteria is necessarily limited by the low temperature to which they are subjected during the greater part of the year. During the winter season their life is suspended, but is not extinguished, since they have been found living and ready to resume all their activity after an indefinite sleep, perhaps of thousands of years, on the ice of the glaciers, where the temperature never rises above the freezing point. When the activity of these ferments in the most unfavorable conditions is recognized, it is easily seen how much more active they become when brought down to lower levels, where they are nourished by the favoring conditions which exist, especially during the summer, in cultivated soils. In fact, the importance of the action of these bodies on the mineral particles of which the soil is largely composed has never been fully recognized, and there is no doubt whatever of the great significance of their decomposing action in the liberation of plant food locked up in undecomposed mineral structures. In this case the activity of the bacteria is not limited to the surface of rock masses, but permeates every particle of soil and thus becomes effective over a vastly extended surface.

When the extreme minuteness of these organisms and of the phenomena which they produce is considered, there may be a tendency to despise their importance; but by reason of the fact that their activity is never ceasing and of the widest application, it must be placed among the geologic causes to which the crust of the earth owes a part of

its actual physiognomy, and to which the formation of the deposits of the comminuted elements constituting arable soil is due.

But the action of these ferments has not stopped with the aid they have given to soil formation. It is highly probable that they assist in a most marked manner in the final dissolution of the soil particles, and the setting free of the plant foods which they contain. It is quite certain that in the primary decay of bare rocks, especially at high altitudes, the nitrifying organism plays a highly important part, preparing the surface of the rock for the first growth of lichens and other low vegetable organisms, from which the first traces of humus are formed. The discovery that the nitrifying organism can subsist upon a purely mineral food is one of the chief supports of the idea that they were especially active in the very beginning of soil formation. It has been shown that these bacteria can be developed by absorbing from the ambient atmosphere traces of ammonia and other bodies which may be present in the air. There is thus discovered in the very first products of the attrition of rocks the characteristic element of vegetable soil, viz.: humus, the proportion of which increases rapidly with the processes of disintegration, until finally the decaying mass is capable of sustaining chlorophyll-containing plants. Not only upon the surface of exposed rocks have these organisms been discovered, but they are found to extend also to a considerable distance in the interior. They not only play an important part by direct action upon the mineral matters which the rocks contain, but later on, through the production of nitric acid, greatly favor the final solution of the soil particles.

Kinds of Organisms in the Soil.—The nitrifying organisms in the soil exist in common with hundreds of others, many of which are doubtless active upon the soil particles. The organisms to which particular attention is called in this address, in addition to those which help to dissolve the soil particles already mentioned, are those which are active in preparing organic foods for absorption and assimilation by

plants, and those which act upon free atmospheric nitrogen, and bring it into a shape suited to plant nutrition.

In general these are called the nitrifying ferments, and their action is uniformly favorable to vegetable growth. Attention should also be given to another class of organisms found in the soil, whose activity is inimical to plant growth or hurtful in some other way. This class comprises the denitrifying organisms, and those of a pathogenic nature which may exist in the soil, and by their activity cause disease in man and beast.

The Nitrifying Ferments.—The micro-organisms of most importance to agriculture, and those to which attention is particularly called in this article, are the bacteria which act upon nitrogenous matters and oxidize them to nitric acid, or which exert a reducing effect on nitric acid, bringing it to lower forms of oxidation, or even to free nitrogen. These organisms belong to many different species, and act in very many different ways. The general group to which they belong is known as nitro-bacteria. The classification of these organisms by genera and species would prove of little interest to the readers of this article. In general it may be said that there are three distinct genera, comprising, in the first place, those organisms which form ammonia or carbonate of ammonia from organic nitrogenous compounds, such as albumin; in the second place, the organisms which transform carbonate of ammonia into nitrous acid; and, in the third place, those which transform nitrous into nitric acid. Each genus is necessary in the complete transformation of proteid matter into nitric acid, in which latter form alone nitrogen is chiefly available for plant food.

Production of Ammonia.—The bacteria which are especially active in the formation of ammonia are found constantly in surface soils and in the air and rainwaters. By the activity of these organisms in the decomposition of proteid matter, large quantities of ammonium carbonate are produced. The organic carbon which is present in a compound is acted upon during the oxidation of the proteid, and carbon dioxide and certain organic acids are formed.

The organic sulphur which is present is converted into sulphuric acid, and the hydrogen partly into water and partly into ammonia. This oxidation is accomplished by bacteria, and, to a less extent, by moulds and yeasts. The table shown on the screen contains the names of the common soil bacteria, which ammonize proteid matters. The column headed "per cent." shows the amount of proteid matter changed into ammonia by the several organisms in twenty days at a temperature of 30°. Of all the bacteria which have been studied, the species mycoides has the highest ammonizing power, being capable of changing nearly half of the proteid into ammoniacal nitrogen in the time named. In soils where the environment does not permit of the development of the nitrifying ferments, the change stops with ammonia. Such conditions are found in the vegetable soils of swamps, which are extremely acid. In such soils ammonia is quite freely produced, while the nitrous and nitric organisms are absent.

In the analysis of a swamp soil, which had been shown by a bacterial culture to contain no nitrifying ferments, 0·03698 per cent. of nitrogen was found as ammonia and only a trace as nitric acid. In another vegetable soil, which contained nitrifying organisms, 0·0336 per cent. of ammoniacal and 0·0474 per cent. nitric nitrogen were present. Of the moulds, several have been found capable of producing considerable quantities of ammonia. Among these *Cephalothecium roseum* converted over 30 per cent. of proteid into ammoniacal nitrogen in five days, and *Aspergillus terricola* was only a little less active.

The yeasts are still less active, but a large number of them produces ammonia in small quantities.

In general, it may be said that in cultivated soils, which have a neutral or alkaline reaction, bacteria are almost the sole ammonia makers, while in vegetable soils of a marked acid reaction, as in swamps and forests, the moulds are the chief producers of ammonia.

In the oxidation of albumin by the *Bacillus mycoides* the carbon is oxidized to carbon dioxide, the sulphur to sulphuric acid and the hydrogen to water and to ammonia.

The reaction may be expressed by the formula

$$\underset{\text{Albumin}}{C_{72}H_{112}N_{18}SO_{22}} = \underset{\text{Water}}{29H_2O} + \underset{\text{Carbon dioxide}}{72CO_2} + \underset{\text{Sulphur trioxide}}{SO_3} + \underset{\text{Ammonia}}{18NH_3}$$

The *Bacillus mycoides*, under certain conditions, can form ammonia also from nitrates. In the absence of oxygen it reduces nitrates to ammonia in presence of an organic substance like sugar. In this action it is anærobic, while in the ordinary process of converting proteid matter into ammonia the action takes place in the absence of oxygen. This is a curious instance of a reverse action produced by the same organism in a different environment, showing, as it does, an oxidizing action in the presence of oxygen, and a reducing action in its absence. Some idea of the character of the *Bacillus mycoides* and the methods of its culture can be gained by a study of the photographs which will now be projected upon the screen.

Production of Nitrous Acid.—The next step in the process of nitrification is the conversion of ammonia or its compounds into nitrous acid. With a moderate store of ammonia the oxidation into nitrous acid takes place, as a rule, without any of the nitrogen being lost in a free state or being volatilized as ammonia compounds. When, however, there is a large excess of ammonium carbonate, a considerable loss of nitrogen may take place. The practical deduction to be drawn from this fact is apparent. Nitrogenous fertilizers should be applied only in moderate quantities, so as not to increase the stock of material beyond the power of the active ferments to handle it.

The nitrous ferment is by far the largest and most vigorous of the nitrifying organisms. It is from three to four times as large as the nitric ferment, and under a high power of the microscope appears as minute globules, slightly oblate. These globules are multiplied by fission and the divided parts develop rapidly to perfect organisms of full size. In most cases the organisms appear as distinct globules, but many are congregated into masses where the distinctive cell structure seems to be lost. A photograph of the nitrous organism is shown upon the screen.

Conversion of Nitrous into Nitric Acid.—The last step in the process of nitrification consists in the oxidation of nitrous to nitric acid. As a rule, plants absorb nitrogenous food only as nitric acid, but it cannot be said that the nitrogen may not be used by the plant in other forms. Some experiments seem to show that ammonia and its compounds and humus may be directly absorbed by plants, but if this be true it must be only in very limited quantities. The final step, therefore, in nitrification is necessary to secure this valuable food in its most highly available state. The nitrifying organisms are much smaller than their nitrous cousins, and of the same general shape, but more globular.

It must not be supposed that these steps in the preparation of a nitrogenous food are performed with entire distinctness. The impression might be obtained that the ammoniacal ferment exerted its activity, converting the whole of the nitrogenous supply into ammonia, and that in this state only the nitrous ferment would become active and convert the whole product into nitrous acid, which finally, under the influence of the nitric ferment, would form nitric acid. In point of fact, however, in arable soils and under favorable conditions, the steps of nitrification may be almost synchronous. In the case of a growing crop, a chemical examination or repeated chemical examinations might find only traces of ammonia and nitrous and nitric acids. As each particle of ammonia is formed, it is converted without delay into nitrous acid, and then at once into nitric acid. The nitric acid formed is absorbed by the growing plant, and thus it might seem that the activity of the ferments present in the soil had been reduced to a minimum, when in point of fact they were exercising their functions with maximum vigor. The separate stages of nitrification mentioned above can only be secured in the laboratory by a skilled bacteriologist patiently working to separate the different genera of nitrifying organisms until he procures them in an absolutely pure form. As may be supposed, this is very difficult to accomplish.

(A photograph of the nitric organism was shown upon the screen.)

Ferments Oxidizing Free Nitrogen.—In the preceding paragraphs the attention of the reader has been briefly called to the action of those species of ferments which attack nitrogen in some of its forms of combination. Since nitrogenous food is the most expensive form of nutriment which the plant consumes, it is a matter of grave importance to agriculture to know the full extent of the supply of this costly substance. It is evident that the continued action of nitrifying ferments finally tends to exhaust the stores of this substance which have been provided in the soil. The quantities of oxidized nitrogen produced by electric discharges in the air and by other meteorological phenomena, and which are brought to the soil in rain waters, are of considerable magnitude, but lack much of supplying the ordinary wastage to which the stores of soil nitrogen are subjected. Even with the happiest combination of circumstances, it is not difficult to see in what way the available stores of nitrogen could be diminished to a point threatening the proper sustenance of plants, and thus diminishing the necessary supplies of human food. The examination of the drainage waters which come from a fertile field in full cultivation, is sufficient to convince the most skeptical of the fact that the growing crop does not by any means absorb all of the products of the activity of the nitrifying ferments. Nitric acid and its compounds, the nitrates, are exceedingly soluble in water, and for this reason any unappropriated stores of them in the soil are easily removed by heavy downpours of rain. Happily the living vegetable organism has the property of withholding nitric acid from solution, either by some property of its tissues or more probably by some preliminary combination which the nitric acid undergoes in the plant itself. This is easily shown by a simple experiment. If fresh and still living plants be subjected to the solvent action of water, very little nitric acid will be found to pass into solution. If, however, the plants be killed before the experiment is made, by being exposed for some time in an atmosphere of chloroform, the nitric acid which they contain is easily extracted by water.

The losses, therefore, which an arable soil sustains in its

content of nitrogenous matter must be supplied either by the addition of nitrogenous fertilizers or by some action of the soil whereby the nitrogen which pervades it may be oxidized and fixed in a form suited to the nourishment of plants. The discussion in regard to the possibility of fixing nitrogen in the soil has been carried on with great vigor during the last two decades. The proof, however, is now overwhelming that such fixation does take place. It would not be proper here to enter into a discussion of the processes by which this fixation is determined, and, in fact, they are not definitely known. One thing, however, is certain, viz.: that it is accomplished by means of micro-organisms or ferments similar, perhaps, in their nature to those already mentioned, but capable of absorbing, assimilating and oxidizing free nitrogen.

Methods of Oxidizing Free Nitrogen.—At the present time, it is sufficiently well known that this operation takes place in two ways. In the first place, there are found to exist on the rootlets of certain plants, chiefly of the leguminous family, colonies of bacteria whose function is known by the effects which they produce. In such plants in a state of maturity, as was mentioned above, are found larger quantities of organic nitrogen than could possibly have been derived from the soil in which they were grown or from the fertilizers with which they were supplied. Cultural experiments in sterilized soils, with careful exclusion of all sources of organic nitrogen, have proved beyond question that this gain in nitrogen is found only in such plants as are infected by the organism mentioned. The logical conclusion is therefore inevitable that these organisms, in their symbiotic development with the plant rootlets, assimilate and oxidize the free nitrogen of the air and present it to the plant in a form suited to absorption. Attempts have been made to inoculate the rootlets of other families of plants with these organisms, but so far without any pronounced success. There are, however, certain orders of low vegetable life, such as cryptogams, for instance, which seem to share to a certain degree the faculty of the leguminous plants in acting as a host for the nitrifying organisms men-

tioned. The observation above recorded becomes a sufficient explanation of the fact that the fertility of fields is increased by the cultivation of leguminous plants, which would not be possible except they possess some such property as that which has already been described.

Another order of organisms has also been discovered which is capable of oxidizing free nitrogen when cultivated in an environment from which organic nitrogen is rigidly excluded. It seems probable, therefore, even in soils which bear crops not capable of developing nitrifying organisms on their rootlets, that the actual stores of available nitrogen may be increased. This fact explains the observation which has frequently been made that in fields which are not cultivated, but which remain in grass, there may be found an actual increase in the total amount of nitrogen which is available for plant growth. As will be seen further along, the soil is also infested with an organism which is capable of destroying nitric acid and returning the nitrogen which it contains to the air in a free state. It seems almost certain that in every complete decomposition of a nitrogenous organism a part of the nitrogen which it contains escapes in the free state. Were it not, therefore, for the fact that this free nitrogen can be again oxidized and made available for plant growth, the total stores of organic nitrogen in existence would be gradually diminished, and the time would ultimately come when their total amount would not be sufficient to sustain a plant life abundant enough to supply the food of the animal kingdom. Thus the earth itself, even without becoming too cold for the existence of the life which is now found upon it, might reach a state when plant and animal life would become practically impossible by reason of the deficit of nitrogenous foods.

Much less is known concerning the character and activity of the organisms that oxidize free nitrogen than of those which feed upon organic nitrogen. It cannot be doubted, however, that these scarcely known ferments are of the greatest importance to agriculture, and the further study of their nature and the proper methods of increasing their

activity cannot fail to result in the greatest advantage to the practical farmer. (Photographs showing the occurrence of the nitrifying tubercules of leguminous and other plants were shown upon the screen.)

Fertilizing Ferments.—Two years ago I used the following words in a report published by the Department of Agriculture:

"When a soil is practically free from albuminoid bodies and contains but little humus, the attempt to develop a more vigorous nitrifying ferment would be of little utility. Even in a soil containing a considerable degree of humus, it may be found that its nitrogen content has been so far reduced as to leave nothing practically available for the activity of nitrification. In such cases the only rational method of procedure is in the application of fertilizers containing nitrogen. In other cases where the lack of fertility is due to the extinction or attenuation of the nitrifying ferment, remunerative results may be obtained by some process of seeding similar to that described above. It is entirely within the range of possibility that there may be developed in the laboratory species of nitrifying organisms which are particularly adapted for action on different nitrogenous bodies. For instance, the organism which is found most effective in the oxidation of albuminoid matter may not be well suited to convert amides or the inert nitrogen of humus into nitric acid. We have already seen the day when the butter-maker sends to a laboratory for a ferment best suited to the ripening of his cream. It may not be long until the farmer may apply to his laboratory for particular nitrifying ferments to be applied to such special purposes as are mentioned above. Because of the extreme minuteness of these organisms, the too practical agronomist may laugh at the idea of producing fertility thereby, and this idea, indeed, would be of no value were it not for the wonderful facility of propagation which an organism of this kind has when exposed to a favorable environment. It is true that the pure cultures which the laboratory would afford would be of little avail if limited to their own activity, and it is only in the possibility of their almost illimitable development that their fertilizing effects may be secured."

It is of interest in this connection to recall the fact that a few months ago the realization of the prophecy above made was accomplished. There is now made, and offered for sale to farmers, a nitrifying ferment called nitragin, which is prepared from the tubercules of certain leguminous plants. It is found that this material is of use only when applied to crops similar to those from which it is made, while it does not act upon other crops, especially those of a non-leguminous nature. For instance, if the farmer wish to fertilize his clover field with a nitrifying ferment prepared in this way, he must get one which is prepared from clover. If it be a field of peas or beans, on the other hand, he must secure a ferment prepared from these vegetables. This process may seem ridiculous to those who do not carefully consider all of its aspects, but in a little phial, no bigger than a goose-quill, can be easily contained the seeds of ferments, which, by proper multiplication, will produce an active nitrification over a large area. In the preparation of the ferment it is best to mix it with fine, moderately moist soil. After thorough mixing, this soil is then sowed over the land as one would sow wheat or oats. By the process of fission the organisms which are thus introduced into the soil rapidly multiply, and if they find the rootlets of plants suitable to their environment they at once attach themselves thereto, where new tubercules similar to the ones you saw upon the screen, are formed. It is too early yet to speak of the commercial success which will attend this method of fertilization, but there is no doubt of the fact that when a field which contains an abundance of nitrogenous matter becomes practically sterilized, this matter may be rendered more available by the introduction of proper nitrifying organisms, and it is also certain that when those crops, such as the leguminosæ, which are suited to the development of the colonies of tubercules upon the rootlets, are seeded with the proper organisms, the number of tubercules is increased, their activity favored, and the assimilation of atmospheric nitrogen hastened.*

* Photographs were exhibited upon the screen to show the influence of inoculating different plants with different ferments developed on radical tubercules.

Ferments Inimical to Agriculture.—It has been noticed by many observers that when nitric acid is subjected to certain fermentative processes it becomes decomposed and gradually disappears. In studying the causes which lead to this decomposition, it is found that it is due to the action of a micro-organism or ferment, which, by reason of the result of its functional activity, is called a denitrifying organism. While it is true that in numbers and activity this denitrifying organism does not equal its nitrifying relation, yet it is a matter of no inconsiderable importance to know fully the laws which govern its existence. As in the case of the bacteria which are found in ripening cream, where some produce evil and some good effects, so it is with those in the soil. The favoring organisms, whose functional activity prepares nitrogen in a form suited for plant food, are accompanied by others, doubtless nearly related to them, whose functional activity tends to destroy the work which the first have accomplished. It thus happens that in the fermentation of nitrogenous bodies there is danger of losing, as has already been said, a part of the nitrogen, which may either escape as gaseous oxides unsuited for the sustenance of plants, or even as free nitrogen. The object, at least the practical object, of the investigation of these denitrifying organisms, should be to discover some process by which their multiplication could be prevented and their activity diminished. At the present time all that is known is that in ordinary circumstances these organisms are not developed in sufficient numbers to prove very destructive. It has already been mentioned, however, that in case of a very great excess of organic nitrogenous matter a considerable quantity of the nitrogen therein contained may, through the action of these organisms, be lost. The practical lesson taught here is to apply nitrogenous foods in a moderate manner and avoid every unnecessary excess.

In the case of nitrifying ferments, it has been seen that nitric acid and carbon dioxide are some of the final products of bacterial activity. In the denitrifying process, on the other hand, free hydrogen and free nitrogen are the results of the final activity of the micro-organisms. In these tubes

which I show you, which are partly filled with gas, the evolution of the gaseous material has been secured by introducing into the sterilized solution containing a nitrate, a denitrifying ferment obtained from a soil taken in proximity to a stable. Experience has shown that stable manures of all kinds contain these denitrifying ferments, and that these are capable of causing considerable waste of nitrogen, unless care is taken in their use. The results of such experiments as these show conclusively that it would be a useless extravagance to use a fertilizer containing nitric acid, such as Chili saltpetre, in connection with stable manures.

Pathogenic Ferments.—There are also other forms of ferments in the soil of an objectionable nature which are not related to the nitrifying organisms. It has been observed in France that, in localities where animals are interred which have died of charbon, the germs of this infectious malady persist in the soils for many years, and that, especially when cereal crops are cultivated upon such soils, there is great danger of contaminating healthy cattle with the same disease. In one case it was observed that many sheep which were pastured in a field in which, two years before, a single animal which had died of charbon was buried, were infected with the disease and died. In like manner, it is entirely probable that the germs of hog cholera may be preserved in the soil for many years, to finally again be brought into an activity which may prove most disastrous for the owners of swine. Every effort should be made by agronomists to avoid infecting the soil by carcasses which are dead from any zymotic disease. Cremation is the only safe method of disposing of such infected carcasses. The investigations of scientists have shown that there are many diseases of an infectious nature due to these germs, and that these germs may preserve their vitality in the soil. Among others may be mentioned yellow fever and tetanus, and the microbe producing the bubonic plague, which retains its vitality in the soil and thus escapes entire eradication.

Use of Sewage as Fertilizer.—For the reasons given above, the agronomist, who also has at heart the health and wel-

fare of man and beast, can hardly look with favor upon any of the plans which have been proposed for the use of sewage from large cities for irrigation purposes. There is scarcely a time in any large city when some infectious disease, due to the activity of germs, does not exist, and the sewage is liable at all times to be contaminated therewith. In view of the fact that the vitality of the germs mentioned above may be continued for a long time in the soil, it is fair to conclude that it is of the utmost importance to avoid the contamination of the soil, where it is to be used for agricultural purposes, with any of the dejecta which may come from those infected with any zymotic disease whatever.

Supplying Lost Nitrogen.—It is evident that if no process of supplying the loss of nitrogen existed, the soil would soon lose its power of furnishing food and raiment for man. The philosopher who studies the system of nature sees in the far future the advent of a time when the environment of man on the earth will be too harsh for his present organization. The slow cooling of the sun, and, consequently, of the earth, is the principal cause of this misfortune. But added to this must be considered the gradual disappearance of carbon dioxide and organic nitrogen, two of the essential components of the environment which makes plant life possible. Diminishing heat and light, disappearing carbon dioxide and organic nitrogen are little by little making the struggle for existence harder.

Nitrogen is lost not only by the action of the denitrifying organisms, but also by the solution of nitrates and their loss in drainage waters. From the sea this loss is restored in part by fish and sea-weeds. This is a practical illustration of the text: "Cast thy bread upon the waters, and it shall return after many days." The organisms that oxidize atmospheric nitrogen supply another part.

Fortunately, living organisms adapt themselves to changes in their environment, and life, therefore, will still be possible when the present conditions of existence shall have disappeared.

A careful study of the causes which produce a waste of nitrogen and those which restore the loss, gives the pleas-

ing assurance that the present kind of man will not die of nitrogen hunger. Some of the best producers of proteids flourish at high latitudes.

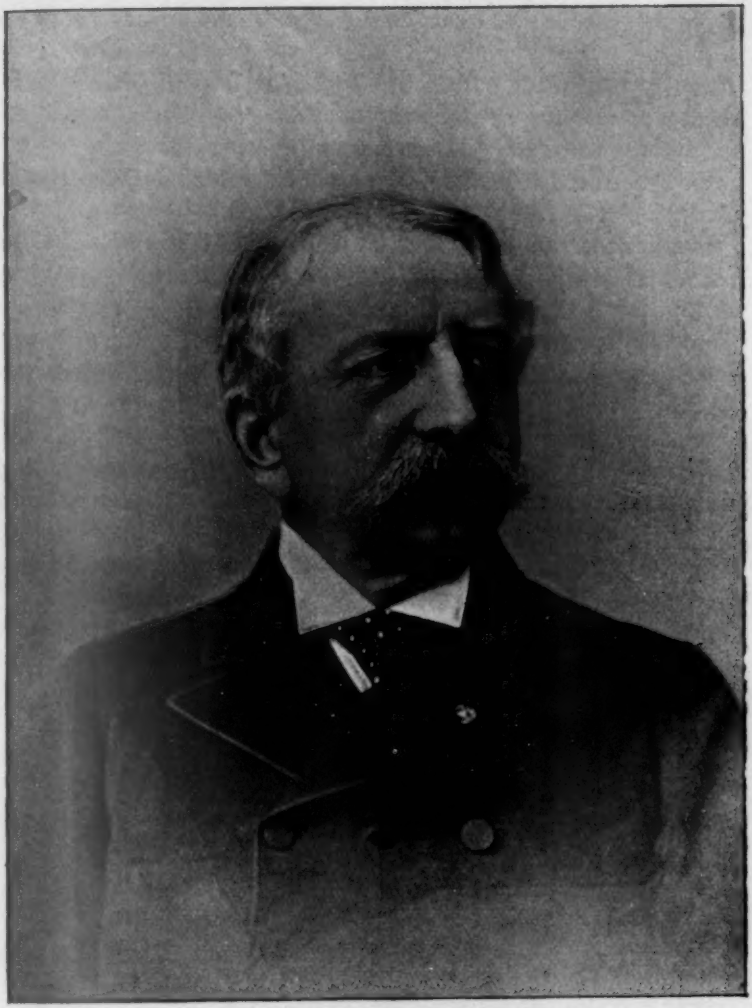
When the last man of the present race, with a stature diminished by long ages of hopeless labor, and with features pinched from hunger and cold, shall have been driven to the equator by the advancing armies of ice, his last look will be at the mocking disc of the sun, denying him warmth, and his last mouthful of food will contain the proteids of oatmeal.

[The lecture was fully illustrated with experimental cultures of soil microbes and by means of lantern slides.]

CHARLES HENRY BANES.

It is fitting, on the death of a public man, that some record should be made of the services he has rendered his fellows. For this reason, the Franklin Institute has appointed a committee to prepare, for permanent record, a brief account of the eminent services the late Charles Henry Banes has rendered it. In presenting this record of the life of their late fellow-member, the committee recognizes that any mere recital of the varied abilities of the man will but inadequately express the extent and value of his public work. In preparing the record the committee has thought it best not to limit the recital to the work he performed in connection with the Institute, but to include therein some reference to his labors and public services in other fields.

Charles Henry Banes was born in the city of Philadelphia, October 24, 1831. He received a public school education, and was graduated from the Central High School of Philadelphia in 1847. At the close of his school life he became interested in mercantile pursuits, in which he continued to be engaged until the breaking out of the war of the rebellion in 1861, when he entered the United States service as Captain of Company E, of the 72d Regiment of



CHARLES HENRY BANES.
1831–1897.

[President of the Franklin Institute, 1886.]

Pennsylvania Volunteers, continuing in the service until June, 1864.

His faithfulness, gallantry and ability in military life are matters of historical record, so that it will only be necessary here to give the following summary. He commanded his company at the siege and capture of Yorktown in 1862, and in the battles of Fair Oaks, May 31, 1862; Seven Pines, June 1st, 8th and 9th; Garnet Farm, June 15th and 18th; Savage Station, June 28th; Peach Orchard, June 29th; Glendale, June 30th; Malvern Hills, July 1st; Chantilly, September 1st; Antietam, September 13th and 17th, and Fredericks, December 13, 1862.

On the 26th of December, 1862, having received honorable mention for gallantry in the Battle of Fredericksburg, in which engagement he was wounded, he was appointed Assistant Adjutant-General, and confirmed by the Senate May 15, 1863.

He took part in the battles of Chancellorville, May 12, 1863; Haymarket, June 24th; Gettysburg, July 2d and 3d, when he was again wounded and honorably mentioned for bravery and gallantry.

He was also engaged in the battles of Robertson Tavern, November 26th; Mine Run, December 2d, where again he was honorably mentioned, and in the Battle of the Wilderness, May 5 and 7, 1864; Spottsylvania, May 8th to the 18th; Po River, May 9th; North Anna, May 23d and 27th; Tolopotomy, May 28th; and Cold Harbor, June 1st to the 4th, 1864, where he was so severely wounded as to be incapacitated for further service. He was breveted Major for his gallantry at Gettysburg, and Lieut.-Colonel after the battle of Spottsylvania.

On his retirement from military life, Colonel Banes became a partner in the firm of George W. Fiss & Co., and shortly afterwards in that of Davis, Fiss & Banes, wool merchants, with which he remained until June, 1872, when he and others began the manufacture of worsted yarns, under the style of Fiss, Banes & Erben. In 1883, he retired from the active duties of this business and became a special partner in the succeeding firms of Erben, Search & Co., and Erben,

Harding & Co. In addition to these business enterprises, he was President of the United States Electric Light Company, and a director in various manufacturing companies, as, for example, the Keystone Watch Case Company, and the John B. Stetson Company.

Nor did he limit himself to undertakings in the manufacturing world; he was also a financier of marked ability. He played an important part in the reorganization of the Hestonville, Mantua and Fairmount Passenger Railway Company, and, at the time of his death, was President of the Market Street National Bank, of which he was one of the originators. He was also one of the directors of the Philadelphia Trust, Safe Deposit and Insurance Company.

In the field of literature he prepared, among numerous other works, "A History of the Philadelphia Brigade," which is justly recognized as of great value, both on account of its historic accuracy and its literary merit.

As to his public life, in 1882, Colonel Banes was elected a member of the Philadelphia Select Council from the Fifteenth Ward, in which capacity he served with distinction to himself and benefit to the public. At various times during his life he was offered the nomination for important offices in the gift of the people, among which may be mentioned that of Controller of the City of Philadelphia in 1884, and that of Mayor of the same city in 1887. He declined these honors.

Colonel Banes was a forcible public speaker, and was much sought after in church, military and civic circles, for addresses. These were always characterized by a charm of expression, logical conclusions and impressive delivery.

In the religious world he was well known in both his own denomination (the Baptist), as well as in evangelical religious circles generally. For a number of years he was President of the City Baptist Mission, in which connection he supported a number of missions, several of which afterwards became large and well-established churches.

As Secretary of the American Baptist Publication Society, he instituted many important business changes, among the most important of which was the construction of

a commodious and well-equipped building at Lombard and Juniper Streets, for the printing and book-making departments of the society. He had plans prepared for a twelve-story office building, at 1420 Chestnut Street, the site of the society's former building. These plans were accepted by the society, and the building is now in process of erection.

Colonel Banes became a member of the Franklin Institute in October, 1874. He was elected to the Board of Managers of the Institute in January, 1877, and continued a member of this body until 1895, when he declined re-election on account of press of business and ill health. He was President of the Institute during the year 1886.

In connection with the work of the Franklin Institute, Colonel Banes is, perhaps, best known, on account of the marked ability, the untiring energy, and the rare executive powers which he exhibited at the International Electrical Exhibition, held in Philadelphia in 1884. Considered from the standpoint of the Franklin Institute, this exhibition may justly be regarded as the most important public work the Institute has ever undertaken. Considered from the standpoint of the electrical world, this exhibition has, probably, done more in advancing the cause of electrical science, by placing on public exhibition the products of electricity from different parts of the world, than has any exhibition held prior to 1884. Nor was this due entirely to the exhibits. At the same time, as a natural outgrowth of the exhibition, a National Conference of Electricians was held under the direction of an United States Electrical Commission, created by an Act of Congress, and approved by the President in May, 1884, the Act authorizing the appointment of a scientific commission, "Which may, in the name of the United States Government, conduct a National Conference of Electricians in Philadelphia in the autumn of 1884."

To those familiar with the excessive labor necessary to carry out successfully the details of a great exhibition, the rare executive ability required properly to select the numerous assistants necessary for the different departments, and the tact and skill required to see that the work is carried out along carefully pre-conceived plans, the pronounced suc-

cess of this exhibition is in itself sufficient evidence of the many-sided abilities of Colonel Banes, who, as the Chairman of the Committee on Exhibitions, and the executive head of the enterprise, proved beyond question both that he was an able business man and a leader of men.

Recognizing the rare opportunities the exhibition afforded for advancing the educational interests of the city, Colonel Banes made arrangements with the Board of Education of the city of Philadelphia to set aside special days during which the students of its public schools could attend the exhibition. Under these plans, upwards of 17,000 students, representing nearly 100 schools and 740 teachers, availed themselves of the opportunity the exhibition afforded as a great object lesson. In order to enable the school children to understand more clearly the general exhibits, a special course of lectures on elementary electrical subjects was provided free of charge, and a prize was offered the students for the best composition on "What I Saw at the Electrical Exhibition."

Nor did the educational features of the exhibition end here. Besides a historical exhibit of electrical apparatus, there was undertaken, under the direction of a committee on bibliography, a collection of electrical books, which resulted eventually in the formation of "The Memorial Library of the Franklin Institute," a library devoted entirely to electrical publications, which holds a high rank among the electrical libraries of the country.

In order still further to instruct the public as to the general nature of the exhibition, in addition to lectures delivered to the general public by noted scientists, the various exhibits were placarded as to their names and the purposes for which they were constructed. Posters were displayed, describing in simple terms their general construction and operation, and, in addition, a series of electrical primers was published and distributed at a nominal cost.

This development of the educational side of the exhibition, which was its characteristic feature, was due largely to the initiative of Colonel Banes as Chairman of the Committee on Exhibition. Under his leading, the exhibition building

became a great school, where the public was able to learn what had already been accomplished by the potent agency of electricity, as well as to form some idea of what was in store for them.

During the exhibition, a valuable series of measurements and tests of electrical apparatus were made, and everything was done to aid the public in obtaining an insight into what they were examining.

From the standpoint of financial success, which, in these days of active business enterprise, is, perhaps, what best shows the ability of a general manager, Colonel Banes' ability may be judged from the fact that the number of paid admissions to the exhibition was 282,779, while the cash receipts from the sale of tickets were nearly $100,000.

During the many months the exhibition building was being erected; during the time that the space was being allotted to exhibitors; while extended correspondence was being carried on with different governments and exhibitors all over the world, and while plans were being laid for the proper carrying out of the financial, mechanical and electrical features of the exhibition, the tact, administrative ability and untiring activity of the chairman were daily manifested, and so assiduously did he apply himself to the work, that before the close of the exhibition his health failed and he was seriously ill for a long time afterwards.

The committee recognizes the inadequacy of this brief record of the work of a many-sided man, a man who attained distinction in the business, financial, military and scientific world, and last, but not least, who was a true Christian. It is willing, however, so far as his connection with the Franklin Institute is concerned, to let the record of the work accomplished by the International Electrical Exhibition of 1884 stand as a record of the services he has rendered to the institution of which he was so long an honored member.

But it was in private life that the most attractive qualities of the man were displayed. His kindly, sympathetic nature, the purity of his life, his unselfish care for his friends, all showed in him the development of a high type of Christian manhood. These peculiarities were best known to his

intimate friends, and are indelibly recorded in their fondest memories.

(Signed) EDWIN J. HOUSTON,
W. P. TATHAM,
H. R. HEYL.

NOTES AND COMMENTS.*

ELECTRIC LIGHTING AND TRACTION.

In the course of a review of the progress of science and the industries during the year 1896, the Philadelphia *Evening Bulletin* contains the following data of interest bearing on the caption of this article:

In the electric lighting field the total capital invested in the United States is given as over $500,000,000. The number of plants, public and private, is over 10,000. The number of motors in use is estimated at about 500,000, and their value at about $100,000,000. The electrical apparatus used in mining is estimated at $100,000,000, and the value of the electric elevator industry will probably not fall short of $15,000,000.

The most important of all the electrical industries, however, is that of electric railways. In this field the investment is very great, and in the United States is represented by a capitalization of over $700,000,000. The number of trolley cars in use is now over 25,000, and these run on over 12,000 miles of track. The electric railways represent more than 90 per cent. of all the street and suburban railroads of the country.

The aggregate of all the capital invested in electric lighting, electric railways and electric power is about $1,500,000,000, and this does not include the value of establishments that manufacture the machinery and apparatus. As many of these are among the largest industrial enterprises in the world, and as nearly all are concerns of considerable magnitude, it is evident that their combined capital will run into large figures.

Now, however, we seem to be on the verge of a practical solution of the problem of obtaining "cold light," or light in which the waste of energy in the form of heat is reduced to a minimum. The earliest exhibited attempt of this kind was the etheric light of D. MacFarlane Moore, of Newark, N. J. Mr. Moore employs as a source of light the vacuum tube, in which, as is generally known, the light is produced by the passage of the electric discharge through the rarefied gas of the tube. In such light there is no combustion and only very little heat.

Another contribution to the same problem is the fluorescent bulb of Mr. Edison, an outcome of his study of the X-ray tubes. The commercial possibilities of these inventions, however, are not yet known.

* From the Secretary's monthly reports.

ELECTRICAL ENERGY DIRECTLY FROM CARBON.

At a recent meeting of the New York Electrical Society, Mr. Willard E. Case presented an interesting paper on "Electricity from Carbon Without Heat."

We give herewith the editorial comments on the paper, expressed by the *Electrical World*. The author paid some attention to the carbon cell recently revived by Mr. Jacques, but added little toward explaining the curious results which are obtained in this form of battery. He finds that if water be present in the caustic soda when first used, the reversion of the electromotive force which Mr. Reed found to exist becomes manifest, and he believes that its presence is the cause for this phenomenon, similar in its nature to that which takes place in the case of a thermo-electric couple. If caustic soda be fused in a nickel crucible, the nickel is not acted upon by the alkali, and therefore acts as an inert negative. Under these conditions no reversal of polarity could be detected; but as the temperature is increased the electromotive force rises to a maximum and then diminishes, finally becoming apparently asymptotic to the temperature axis. This fact is opposed to that presented by Mr. Reed, who found a reversal of the electromotive force as the temperature increases. The discrepancy may possibly be explained upon the assumption that the radiation of heat from a nickel crucible in Mr. Case's experiments is sufficient to prevent an increase of temperature above a certain point. The erratic performance of the cell in which an iron vessel is employed clearly showed that there remains considerable room for investigating the action of this type of carbon battery. One of the most interesting and suggestive points which Mr. Case brought out is the possibility of discovering a method of obtaining electricity from carbon without heat, by following nature's plan in the human system, and instead of having the entire transformation take place within the carbon-conveying cell, previously prepare outside the cell the material to be used.

ELECTRICAL NOTES.

Houston and Kennelly have lately presented to the American Philosophical Society an elaborate paper, in which they have sought to demonstrate that *the insulating substance* surrounding an electric conductor *is the true path of the current*. The Edison Company, of New York, is reported to be substituting the Thomson *mechanical wattmeters* in place of the old chemical meters. Following out the interesting experiments of Becquerel, which showed that certain salts of uranium, after exposure to sunlight, emitted radiations which, like the *Röntgen rays*, were capable of affecting photographic sensitive plates through intervening opaque substances, Professor McKissick, of Auburn, Ala., as the result of numerous experiments, announces his belief that the Becquerel ray is the connecting link between the ordinary light and the Röntgen ray. A full account of Professor McKissick's experiments appears in a recent impression of the *Electrical Engineer*.

ORIGIN OF PETROLEUM.

Much of scientific interest attaches to certain recent investigations designed to throw light upon the mode of origin of petroleum. Mendeléef endeavors to answer this question by assuming a mineral origin for petroleum, through the chemical interaction of steam upon metallic carbides assumed to exist at great depths.

Engler has recently demonstrated experimentally the artificial production of hydrocarbons of the paraffin series in the destructive distillation of animal fats under pressure. This interesting fact greatly strengthened the view of many chemists, that natural stores of petroleum had their origin in the decomposition of animal remains under peculiar heat and pressure conditions.

Sadtler now supplements the work of Engler by demonstrating that petroleum hydrocarbons are produced in the destructive distillation, under pressure, of linseed oil, a product of vegetable origin.

The results obtained by Sadtler, therefore, would permit the conclusion that native petroleum was derived from the decomposition of vegetable remains and reopens the whole question. W.

THE BRADLEY ALUMINUM PATENT DECISION.

A recent decision of the United States Circuit Court of Appeal, confirming the ownership by the Cowles Electric Smelting and Aluminum Company, of certain patents issued to Charles S. Bradley in 1891-1892, may have an important bearing, not only upon the aluminum industry, but also on a number of related industries, notably on the manufacture of carborundum, calcium carbide, and other products which depend upon what is technically known as "electric smelting."

Passing by certain special points at issue in the case, the vital element embodied in the decision is the broad interpretation placed upon the Bradley patents, and which, if we properly apprehend it, will permit its owners to manufacture and to license others to manufacture any and all the metals and compounds which may be produced by the process of electric smelting from highly refractory ores and compounds, which are non-conductors in their unfused state.

To what extent this decision may interfere with the industries already established can only be conjectured at this time, and the consideration of this phase of the subject is foreign to our purpose.

Briefly stated, the Bradley invention, which bears most directly on the aluminum industry, contemplates the reduction of refractory ores (of which the ores of aluminum may serve as an example), which are non-conductors in their unfused state, by fusing the mixture, utilizing the heating action of the electric current, and then decomposing the fused compound by the electrolytic action of the same current. The process is made continuous by charging the bath with fresh quantities of the ore or compound as the reduction proceeds. The gist of this invention, from this, would appear to be to do away with the serious difficulties attending the use of heat externally ap-

plied to effect the fusion of many refractory ores (such as those of aluminum), by using for this purpose an electric current of greater quantity than will be needed to effect electrolytic decomposition after the fusion is once made. Thus, the current is caused to perform two distinct functions: one fraction of the electrical energy is continuously expended in fusing and maintaining the fusion of the refractory mixture, thus rendering it conductive; while the remaining fraction effects the electrolytic decomposition.

To those familiar with the operative details of the electrolytic method in vogue for the manufacture of aluminum, the completeness with which all the essential features are covered by this invention will need no further comment. The fifth claim of this patent (No. 468,148, February 2, 1892) might well stand for a concise description of the present electrolytic process by which aluminum is now exclusively manufactured, viz.:

> "(5) The continuous process of separating or dissociating aluminum from its ores or compounds, consisting in fusing and maintaining the fusion and electrolytically decomposing the ore or compound by the passage of the electric current therethrough and charging the bath with fresh quantities of the ore or compound as the reduction proceeds, substantially as set forth."

Two other patents are considered in the same decision, into which it will be unnecessary to enter.

The court's interpretation of the scope of the three patents would appear to cover not only the ground referred to in the foregoing allusions to aluminum, but also the process of "electric smelting" in general, it being held that "the language of the Bradley claims is broad enough to admit the admixture of carbon, if his invention was a primary one, and the employment of carbon was a mere auxiliary of the current in effecting the reduction."

W.

TELEGRAPHY WITHOUT WIRES.

An article in the March number of *McClure's Magazine* describes the experiments now being conducted in England by Gugliemo Marconi for telegraphing without wires, to which the following reference appears in the *Electrical World:*

At the Liverpool meeting of the British Association, Mr. W. H. Preece called attention to these experiments, which have been conducted since with his collaboration. Mr. Marconi's results are remarkable. He seems to have discovered a new form of electrical wave, somewhat similar to the Hertzian wave, yet differing greatly in its penetrative power. On Salisbury Plain he has succeeded in sending intelligible signals a mile and three-quarters, while during some former tests signals were exchanged between two points separated by a hill three-quarters of a mile thick. It is the belief of the inventor that his new waves will penetrate all substances.

The inventor and Mr. Preece are now working at Penarth, in Wales, to establish regular communication with a lightship some miles at sea. It has been proposed to establish, in connection with lighthouses, a constant source of

electrical waves, which will penetrate the densest fog and make themselves evident on shipboard to proper receivers.

In regard to the use of this system in naval operations, Mr. Marconi speaks of a curious danger to be apprehended from induction sparks, which might explode the magazine of a warship.

ELECTRO-CAPILLARY LIGHT.

In a contribution to *Wiedemann's Annalen*, No. 12, Herr O. Schutt, of Jena, describes a new electric discharge phenomenon, which he terms electro-capillary light. When the discharge of an induction coil is sent through a narrow capillary tube of about 0·05 millimeter in diameter, provided with aluminum or copper electrodes and filled with air under ordinary pressures, an intense luminosity of the thread of air is obtained—a luminosity which is intrinsically far superior to that of the arc, and would form an exceedingly powerful source of light, if it could be made continuous. The narrow capillaries deteriorated rapidly, roughening inside, and were blown into a series of spherical enlargements. Wider tubes gave less light, but were much more permanent. At the same time the bright lines in the continuous spectrum in the original light became more prominent. At pressures above one atmosphere the phenomena were nearly the same, but the sparks passed with greater difficulty. At low pressures the light became less intense, the continuous spectrum faded, and the bright lines shone out more distinctly. The kind of glass is immaterial. It is stated that the tubes may be made 20 centimeters long and make splendid line sources.

THE LAKE WATERWAY.

Probably no expenditure ever made by the Government, says the *Engineering and Mining Journal*, has been of greater benefit to the nation than the money employed in improving and maintaining navigation on the Great Lakes. It is the lake waterway which has made the development of the iron ores of Michigan, Minnesota and Wisconsin possible, and has enabled the iron ranges of the Lake Superior region to furnish the industry in the United States with a supply of iron ores, without which its growth would have been far less rapid than it has been. The copper industry of Michigan has been also very greatly benefited. Taking these two great interests alone, the return has been far greater than the amount invested, to make no mention of the agricultural industries of the West.

The enormous value of the lake traffic is shown by the fact that in 1895—the figures for 1896 are not yet complete—the vessel traffic passing through the Detroit River, where nearly all the tonnage of the lakes meets, exceeded by 10,000,000 tons the total foreign trade of the United States. The freight carried was 29,860,335 tons and the distance covered by it reached the enormous total of 22,395,251,250 ton-miles. This great amount of freight, moreover,

was carried at an extremely low rate, the average being estimated at 0·085 cent per ton-mile—probably the lowest price for which freight is transported anywhere in the world. In this country the railroad rates are less than in any other except British India; but about the lowest charge known here is that on Pocahontas coal to tidewater, which is not far from 0·25 cent, or three times the lake rate. The average trunk line rate on heavy through freight is 0·45 to 0·60 cent, or from five to seven times the lake rate.

The effect of this extremely low rate, on the iron ore industry especially, can be estimated only by the fact that the shipments have reached a total of 10,000,000 tons a year.

The figures which best illustrate the growth of the lake traffic are those which give the business passing through the Sault Ste. Marie Canal. We have given the statement for the years 1885, 1890, 1895 and 1896 to illustrate the growth of business:

Year.	*No. Vessels.*	*Tonnage.*	*Tons Freight.*
1885	5,380	1,035,937	3,256,628
1890	10,557	8,454,435	9,041,313
1895	17,956	16,806,781	15,062,580
1896	18,615	17,249,418	16,239,061

The estimated value of the freight last year was $160,000,000. It must be remembered that the canal is closed by ice for about one-third of the year; in 1896 it was open 234 days.

The only great maritime canal at all to be compared with this is the Suez Canal; and during the latest year for which figures are available, that waterway passed 3,352 vessels, with a total registered tonnage of 8,039,105, or 9,110,313 tons less than were recorded at the Sault last year.

Perhaps these figures should not surprise us, when we remember that over 60 per cent. of the iron ore supply of the United States last year came from the Lake Superior mines, and that nearly all of it took the water route to market. Taking the rates paid on this ore by lake, we find that if the ores had been carried by rail at the usual average of the roads west of Cleveland and the other lake ports, the charges on this ore would have exceeded the freight actually paid by some $2.50 per ton; that is, the cost of every ton of pig iron made from lake ore would have been increased by $4.

This instance alone is sufficient to show the importance of the lake waterway, to both the mining and manufacturing industries, and others equally striking could be given, did space permit.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, March 17, 1897.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 17, 1897.

JOHN BIRKINBINE, President, in the chair.

Present, 102 members and visitors.

Additions to membership since last report, 16.

A letter was read from Mr. Alfred C. Harrison, presenting his resignation as Vice-President of the Institute. The resignation was, on motion, accepted, and, in due form, Mr. Theo. D. Rand was elected to fill the vacancy.

A communication was read by the Secretary, transmitting the following resolution, passed by the Board of Health of the City of Philadelphia, at a meeting held March 16, 1897, to wit:—

"RESOLVED, That the Franklin Institute be requested to appoint a committee to confer with the Board of Health with a view of taking action to abate or modify the smoke nuisance."

The communication was referred to the Committee on Science and the Arts.

Lieut. B. W. Dunn, Ordnance Department, United States Army, presented a paper giving, in brief, an account of investigations conducted during 1891-1892, which resulted in the invention of "A Photographic Method of Measuring the Intensities of Impulsive Forces." The apparatus and its serviceability in measuring the explosive force of various powders were illustrated with the aid of the projecting lantern, and the speaker dwelt especially upon the application of the apparatus in the determination of the resistance of materials employed in engineering works.

The subject was referred for investigation and report to the Committee on Science and the Arts.

Mr. Lewis G. Rowand presented a description of "An Improved Safety Device for Electric Circuits." The speaker exhibited the device, and gave an experimental demonstration of its mode of operation.

Mr. Barnett gave a brief oral account of the evolution of the mechanisms employed in the so-called "Portable Fire Extinguishers," with especial reference to an improved form of this apparatus, manufactured by the Stempel Fire Extinguisher Manufacturing Company, of St. Louis.

The Secretary reported certain experiments devised and shown in a lecture delivered before the Institute, by Prof. Jacobus, of the Stevens Institute of Technology, illustrating the comparative value of the Welsbach incandescent gas light and the acetylene light, in rendering colors and shades of colors, demonstrating not only that these modern illuminating methods were greatly superior in this respect to coal-gas and the incandescent electric light, but also that there was very little difference between them.

Adjourned.

WM. H. WAHL, *Secretary*.